POLIOMYELITIS

BY

W. RITCHIE RUSSELL

C.B.E., M.D. (Edin.), D.Sc. (Oxon.), F.R.C.P. (Edin.), F.R.C.P. (Lond.)

DIRECTOR, DEPARTMENT OF NEUROLOGY, UNITED OXFORD HOSPITALS
CLINICAL LECTURER IN NEUROLOGY, UNIVERSITY OF OXFORD
CONSULTANT NEUROLOGIST TO THE ARMY

SECOND EDITION



LONDON

EDWARD ARNOLD (PUBLISHERS) LTD.

First published 1952
Second edition 1956

PREFACE TO FIRST EDITION

THE writer has during recent years been concerned with several research projects connected with poliomyelitis, and has come to feel that there are advantages in surveying some of the problems presented by this disease from outside the main " battle areas ". There are several varieties of specialist handling these cases, and it seems to be no one's task to study the disease as a whole, or to organize improved methods of diagnosis, treatment and research. It may be helpful therefore to review some of the many aspects of poliomyelitis in the light of current knowledge. This makes it evident that there is a special need in this disease for the scientific assessment of new methods of treatment which may be advocated from time to time One of the chief purposes of writing this book, for example, is to emphasize that the value of the various methods of handling paralysed muscle can be subjected to simple physiological tests, so much so that there is no excuse for perpetuating indefinitely the grossly differing plans for treatment which are now practised

It is evident that the existing arrangements in Britain and also in other countries are inadequate to meet the requirements of either major epidemics or of sharp local outbreaks of the disease It is felt that a general review may contribute to an understanding of what is needed to improve matters

This book attempts therefore to provide information and to comment on many aspects of poliomyelitis which it is hoped will be helpful to those who are already interested in the disease. The writer is very much aware, however, that in certain respects, such as those concerned with the recent virus researches and epidemiology, his comments must appear to be amateurish and out of date to the expert in these fields

A few references are given in the text, but no attempt can be made to do justice to the vast literature of the disease, which may be conveniently referred to in the Bibliography (1949) and its supplements published by the National Foundation for Infantile Paralysis

I am indebted to the Editors of the *British Medical Journal*

CHAPTER PAGE

VI. MANAGEMENT AND TREATMENT 56

Minor Illness Major Illness The Pros and Cons of Transfer to Hospital Isolation. Provision of Adequate Hospital T[illegible] Special Resp[illegible] pital Care. [illegible] Principles of [illegible] and Passive [illegible] ment of Paralysis.

VII. TREATMENT OF BULBAR POLIOMYELITIS . . . 68

Postural Drainage Medical and Nursing Supervision. Respiratory Failure combined with Pharyngeal Paralysis The Copenhagen Method—Intermittent Positive Pressure Artificial Respiration (I P P R) Mechanical Pumps for I P.P R. Radcliffe Respiration Pump Wave Form.

VIII. MANAGEMENT OF INTERMITTENT POSITIVE PRESSURE ARTIFICIAL RESPIRATION (I.P.P.R) . . . 79

Clinical Advantages of I P P R Transporting the Patient Humidifier. Expiratory Valve Pressure Gauge Tracheal Tube Ventilation Pulmonary Complications Blood Pressure Feeding, the Biochemical Control Nursing Disadvantages Mechanical Coughing

IX. TREATMENT OF RESPIRATORY PARALYSIS IN SPINAL CASES 88

Tank Res[illegible] Putting the Patient in a Resp[illegible] Safety Devices [illegible] Ventilation [illegible] Respirators Rc[illegible] Respirator Units

X CARE OF MUSCLES AND JOINTS 101

Muscle Spasm, Shortening and Contracture Dangers of maintaining Relaxation of Paralysed Muscle Splints Nurse and Physiotherapist Hot Packs Passive Movements

XI. CONVALESCENCE AND REHABILITATION 108

Care of Weak Muscles Methods of Testing Rehabilitation Methods Research Report on Rate of Recovery and Effect of Fatiguing Exercises Physiology of Recovery Muscle Fatigue

CHAPTER PAGE

XII PHYSIOTHERAPY 124

Muscle Charts Muscle Treatment Trick Movements The Patient's Psychology. Heat, Massage, Electricity, etc Hopeless Muscles Prevention of Deformity, (a) Due to

pital Treatment Planning the Patient's Future Self-help Devices

XIII. FUTURE PROSPECTS . . . 136

Plan to conquer paralytic poliomyelitis

REFERENCES 138

INDEX . . 145

CHAPTER I

INTRODUCTION

THERE is evidence that poliomyelitis occurred in very ancient times, but the disease only became a well-established clinical entity in the later decades of the nineteenth century. The names of Heine and Medin are specially connected with elucidation of its clinical and epidemiological features.

The textbooks of sixty years ago give some excellent accounts of the disease. Thus we read in Gowers' textbook (1892, p 351)

Acute Atrophic Paralysis; Acute Anterior Poliomyelitis; Infantile Paralysis, Essential Paralysis of Children

> Acute atrophic paralysis is a disease in which voluntary power is lost in the course of a few hours or days, and in which some of the paralysed muscles undergo rapid wasting while others recover The onset of the palsy is often preceded or accompanied by indications of general disturbance. The muscles which waste usually remain weak, and contraction of their opponents leads to permanent distortion of the paralysed limbs

THE VIRUS

The infectivity of poliomyelitis was demonstrated by Medin when he studied the epidemics in Sweden of 1887 and 1895 Later a spinal cord emulsion from fatal cases was used successfully to transfer the infection to monkeys, and since then, the science of virology has developed into the enormous research effort now in existence No attempt will be made in these pages to pay adequate tribute to the many scientists who have contributed to knowledge regarding this disease, and for this purpose the reader is referred to the *Bibliography of Infantile Paralysis*

Three distinct types of human poliomyelitis virus have so far been identified by their immunological properties These are named "Brunhilde" (Type 1), "Lansing" (Type 2) and "Leon" (Type 3), and these viruses are among the smallest known, measuring 10–30 mμ The viruses may live in the human

alimentary canal for long periods, and during epidemics of poliomyelitis they can be recovered from sewage. Carriers of the virus are likely to contaminate their hands and thus spread infection to food. Further, it has been found that house-flies may carry the virus during epidemic seasons In general, therefore, the spread of the virus depends on poor hygiene, but direct droplet spread of infection may also be important.

One might have thought that with improved Public Health Services the disease would become less common, but unfortunately the reverse seems to be the case, for the least hygienic countries have less paralytic poliomyelitis than have their up-to-date counterparts. The cause of this disconcerting state of affairs is uncertain, but it seems probable that in the less hygienic countries the newly born infant is first protected by transmitted immunity from the mother, and as direct infection is inevitable soon after birth, immunity is built up safely during the early months of life (Paul *et. al.*, 1952). On the other hand, infants born in the relative cleanliness of modern civilization may live for many years without developing immunity to common strains of the virus, and we must therefore face the fact that a proportion of our present population of all ages has little or no immunity to dangerous strains of poliomyelitis virus.

The current opinion regarding poliomyelitis is that it is primarily an *infection of the alimentary canal, and a systemic* infection which affects a considerable proportion of the population during an epidemic, but in relatively very few cases causes paralysis. A large proportion of contacts without symptoms are *found to be excreting virus in the stools*

Poliomyelitis viruses are highly resistant to chemical agents such as detergents and most disinfectants. In infected stools left at room temperature the virus may remain active for several *months if not allowed to dry*; and is most easily rendered inactive by heat above 60° C (W H O. Report, 1954).

Paralysis and Poliomyelitis

Poliomyelitis is a very minor illness in the abortive * form, and even when meningitic symptoms develop there may be quick recovery without paralysis (non-paralytic form of the disease).

* The stages of the disease are described on p 16

In the dreaded paralytic form of the disease, however, the virus exhibits some very remarkable characteristics By far the most important of these is its unfortunate affinity for motor cells in the brain and spinal cord (motoneurones) (Figs. 1, 2, 3 and 4). Sometimes in the acute stage there has been evidence of other tissues, such as muscle, being invaded by the virus; but the involvement of other cells and tissues, if it occurs, is of relatively little importance, for tissues such as muscle can regenerate. For example, in Coxsackie virus infection in mice (Melnick and Godman, 1951), necrosis of muscle is followed by regeneration and full recovery of the muscles concerned On the other hand, a nerve cell once destroyed can never be replaced. Bodian (1948) has counted the anterior horn cells surviving after the disease as it occurs in monkeys and man, and has shown a clear correlation between their number and the severity of paralysis He found, for example, in monkeys that as much as a third of the motoneurones to a limb may be destroyed without there being any detectable weakness. When, however, there is very severe or total paralysis, over 90 per cent of the anterior horn nerve cells to the paralysed limb have disappeared. In other grades of paralysis also there was a close correlation between the severity of paralysis and the number of motoneurones destroyed

Pathway of Infection to Nerve Cell

There is uncertainty as regards the route of infection to the motoneurones in the spinal cord or brain (see Bodian, 1952). It is generally thought that the virus must gain entrance to the body via the nose and alimentary tract (pharynx or bowel), but how it gets to the motor nerve cells is not certain. In the experimental animal, it has been shown that the virus can be made to travel from muscle to spinal cord or to travel up from the cut end of a nerve to the spinal cord.

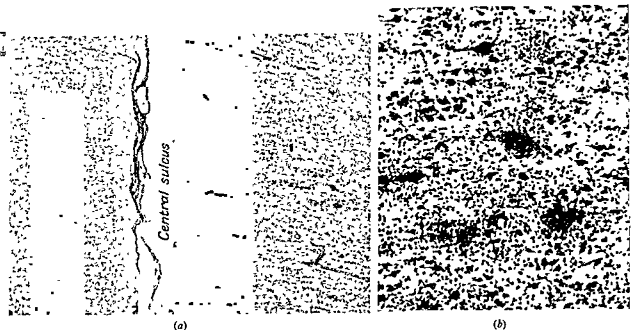
It has for long been known that the virus multiplies in the alimentary canal and the nerve cells, but recent achievements in growing it in tissue culture suggest that the virus may multiply in many bodily tissues Further, the recovery of the virus from *the blood stream after infection* by the oral route (Horstmann, 1952) suggests that the blood stream may provide a direct pathway for the virus to the central nervous system This is a matter



(*a*) (*b*)

FIG 1 (*a*) and (*b*) —Section of spinal cord from a patient (case 34) who died of poliomyelitis after an illness which lasted only for a few days.

Nearly every anterior horn cell in the section has already been destroyed. Nissl. × 18 and × 146.



(a) (b)

FIG 2 (a) and (b) —The motor and sensory cortex of the brain in the same case, No 34.
Cell destruction in the motor cortex is very evident (right of Fig 2 (a) and (b)), while the sensory cortex seems to be intact Nissl, ×28 and ×126

... (Bodian, 1952) There are therefore great hopes that the current experiments with active immunization may be successful (see Chap XIII).

The virus apparently enters the nerve cell several days before the onset of the major illness with meningitic symptoms (Bodian and Howe, 1945), and even in abortive cases the virus may still have invaded the nervous system (Horstmann, 1947). It seems

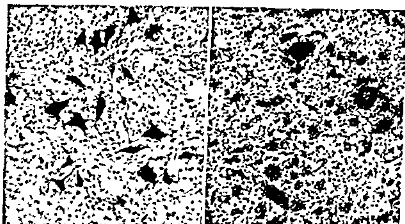


FIG 3—The spinal cord from a case of severe spinal poliomyelitis (death 5 weeks after acute illness) compared with a corresponding part of a normal spinal cord (left)

that the onset of meningitic symptoms corresponds to a highly dangerous phase of virus multiplication within the nerve cells.

Thus, the viruses which cause poliomyelitis have several barriers to overcome before they can reach the spinal cord, but even after entering the nerve cell, they may still be resisted so effectively that no paralysis occurs.

The duration of the meningitic phase before paralysis develops varies within such wide limits (from about one day to two weeks)



(*a*) (*b*) (*c*)

FIG 4 (*a*), (*b*) and (*c*) —Spinal cord, nerve roots and cauda equina for a *chronic case of severe paralysis following* poliomyelitis

The motor roots (M) are normally just as large and as white as the sensory roots (S), but here they are thin and transparent owing to the demyelination of nerve degeneration caused by loss of the spinal cord motor cells

hovers between the allowing of complete recovery and the causing of a disastrous paralysis in a way that is highly disconcerting to the physician.

This uncertainty is reflected also in the wide variation in the duration of the incubation period. Taking this as the interval between exposure to the virus and the development of the major illness the incubation period may vary from three days to five weeks (Horstmann and Paul, 1947).

A Few Critical Hours or Days

The liability to motor cell destruction is presumably influenced by the total dose of virus and its type and by the patient's immunological state, but the curious uncertainties of the clinical course force attention on the possibility that the physiological state of the host and his cells play an important rôle in deciding the fate of the motor cells. For example, it is well known that neither the severity of the meningitic symptoms nor the degree of the cerebrospinal fluid reaction in the pre-paralytic phase bears any relation to the occurrence or not of paralysis. Nor does the duration of the pre-paralytic phase bear any relation to the severity of paralysis. Yet it seems probable that the fate of tens of thousands of nerve cells is decided during a period of a few hours at a critical phase in the meningitic stage. If we ever come to understand fully those biochemical and physical factors which determine motoneurone vulnerability, then knowledge of the time at which the nerve cell becomes invaded by the virus, and the stage at which the invaded cells becomes irretrievably lost, will facilitate attempts at specific forms of treatment. Once the destruction of nerve cells begins, the process is quickly completed, and paralysis seldom spreads for more than about three days Then, after some days of little change, the weak muscles slowly begin to increase in strength, and the main battle is over. Some of the factors which are known to influence this virus-cell struggle are considered in Chapter V.

Fate of the Motor Nerve Cells

According to Bodian's researches, the cells which have been destroyed by the virus can be identified histologically almost as

soon as paralysis appears (Figs. 1*a* and *b*), and these cells disappear entirely in the course of a few days. All the other anterior horn cells, though showing chromatolysis in the acute stage of the disease, recover to a normal appearance in four or five weeks' time.

Histological studies in fatal human cases (Fig 3) indicate, however, that cellular reaction may persist for many weeks. Even so, the recovering motor cells must soon become functionally active, and there is considerable doubt as to why paretic muscles continue to increase in strength for so many months after the acute illness As far as is known, nerve fibre regeneration does not occur in recovering poliomyelitis If the anterior horn cell is only injured to a reversible extent, Wallerian degeneration does not occur in the axon, while if the cell dies there is no possibility of regeneration. There is of course no chance of nerve cells growing again, so one can only conclude that the improved function during rehabilitation depends simply on getting the most out of the remnants of the army of motoneurones which survive the acute illness There are about 12,000 motoneurones supplying the nerves to each limb, and in severe paralysis over two-thirds of these (8000) will be destroyed (Bodian, 1948). There are occasional clinical reports of muscles beginning to act after eighteen months' complete paralysis, but it seems probable in such a case, that the function of the muscles cannot have been properly studied at an earlier date.

The gradual improvement spread over twelve to eighteen months may be due simply to hypertrophy of non-paralysed muscle plus the gradual enlargement of nerve cell and nerve fibre which has been shown experimentally to develop under conditions of continual muscle stress (Edds, 1950); but perhaps even more important is the demonstration by Eccles (1953) that the organization of the spinal cord connections is much less rigid and more alterable than [illegible]

disorder of function of normal excitability of closely related surviving cells It is *probable, therefore, that much of the* recovery of paralysis observed is due to the re-establishment of transneuronal activity which was disrupted in the acute illness not by disease of the cells concerned but by a functional effect of

the disappearance of closely related cells. It is probable that the reorganization of the spinal cord cells requires many months of practising active movement to establish the optimum functional result. This, indeed, is a remarkable characteristic of many spinal lesions, such as spinal concussion, in which improvement occurs during a period of well over a year.

There is some experimental evidence that surviving neurones may branch to innervate neighbouring muscle fibres which are denervated (Hoffman, 1950). This is unlikely to achieve much in the way of functional gain in muscle strength, as the anterior horn cells already each supply a large number of muscle fibres.

Hodes, Peacock and Bodian (1949) have shown that the virus causes a selective destruction of the largest motoneurones. The effect of depriving muscles of the influence of the largest motor cells is not fully known, but it might possibly account for the undue tendency to fatigue sometimes shown by the surviving motor units (see p. 113).

The lack of precise knowledge regarding the physiological basis of clinical improvement leads to much uncertainty regarding the principles on which rehabilitation should be based, and as steady clinical improvement occurs with all forms of treatment, many contradictory claims are made as to what is best. The matter is discussed later (p. 109).

CHAPTER II

INFECTIVITY, QUARANTINE, EPIDEMIOLOGY AND PREVENTION

It is difficult not to be somewhat defeatist regarding attempts to control case-to-case infection in poliomyelitis if, as many *authorities maintain, a large proportion of the population during* epidemics is infected with the virus, and, if they are ill at all, only experience a mild catarrhal illness with no paralysis (Horstmann, 1949). In assessing the seriousness of, say, an outbreak of poliomyelitis in a boarding school of 500 pupils, it should be pointed out that, according to these views, if every pupil in the school of 500 is infected, only two or three are likely to develop the paralytic form of the disease; most of the others, however, will acquire a useful immunity It is arguable, therefore, that children at school cannot be entirely protected from such infection, and that they should be kept at school but should be under careful supervision during the outbreak, so that any threat of a major illness would at once be recognized and properly treated. Unfortunately, in some local outbreaks in non-immune communities the incidence of the paralytic disease is occasionally much higher, even up to 10 per cent of the population at risk, so there is also something to support the view that children with suitable home conditions should be removed by car and isolated at home, if only to reduce the crowded conditions under which these local outbreaks may occur. It is most desirable during local outbreaks of the disease that hand-washing hygiene should be taught, and that uncooked foods should be avoided or carefully washed and protected from contamination. It is the unexpected appearance of the major illness which is specially dangerous, for if the major illness develops when no one is thinking of poliomyelitis, grave errors in management are liable to occur Where parents decide that the children should return home from boarding school, great care should be taken to minimize the risk of the child travelling during the early hours of the major illness (p 56)

If quarantine is to be enforced, a period of two weeks from the last date of personal contact is generally advised. In Britain, diagnosed cases of poliomyelitis are generally isolated with "typhoid precautions" for three weeks, but this period has been reduced to three or four days in some American hospitals.

Distribution of the Virus

An important contribution to this problem has been reported by Melnick and Ledinko (1953). They point out that the numerical ratio of clinical cases to inapparent infections is basic to the understanding of the epidemiology of the disease. The roller tube cultures of the virus in monkey tissue have made it possible to demonstrate neutralizing antibodies quite easily in individuals These workers, therefore, studied the development of neutralizing antibodies against three types of poliomyelitis virus in 200 children during a severe epidemic in North Carolina This epidemic caused an incidence of recognized poliomyelitis of 62 per 100,000, the ratio of paralytic to non-paralytic cases being 2 to 1. None of the children tested developed a disease resembling poliomyelitis, and yet a large proportion of all age groups developed immunity which was previously lacking The previous epidemic in this area had been four years earlier and this was reflected in the low incidence of immunity in the children under four years of age for types 1 and 3 which had been isolated from cases in the earlier outbreak New-born children were an exception where immunity to all three types of virus was found in 70 to 90 per cent of cases—a figure which presumably represents the maternal state The early immunity had largely disappeared by the age of six months.

A high proportion of all age groups greatly increased their immunity to types 1 and 2 during the epidemic, and it was possible from this to calculate directly the proportion of inapparent cases which occurred. This calculation indicated that under 1 year of age there were 175 inapparent infections for every clinical case The corresponding figure for children of 1–2 years was 100, 3–4 years, 73; 5–9 years, 62; 10–14 years, 95.

Immunity to type 3 virus was unaffected in this epidemic as also was immunity to the Coxsackie, the influenza and the mumps viruses.

This study, which contains much other important material, is the first time that the ratio of subclinical to paralytic cases has been directly estimated. This study fully supports the view that contact with the virus is very common, even though few frank cases develop Bodian and Paffenbarger (1954) have demonstrated a high frequency and specific antibody response among household contacts of cases of paralytic poliomyelitis. Similar studies are now being carried out in many other countries. There had been much controversy on the value of the isolation of contacts, the dangers of not using strict isolation techniques, etc., and no firm answer can be given on the facts now available. The various measures advised from time to time are based on theoretical considerations, as it is extremely difficult to prove that one way of dealing with an epidemic is better than another—perhaps the varying regulations of different countries may in time provide valuable information for comparative purposes.

If most children come in contact with the virus sooner or later, we must do everything possible to ensure that their infection leads to immunity without illness. Here is a clear lead to active immunization which is now being quickly developed, so that it is to be hoped that before long all children can be safely exposed to an attenuated vaccine and thus develop adequate natural antibody to protect the central nervous system throughout life

The virus can be isolated from the stools in the acute stages and for three or more weeks after, and this is the main source of infection. However, the virus may also sometimes be recovered from the throat for a few days during the acute stage of the major illness

Difficulties of Control Measures

The doubts and arguments about the importance of isolating suspected cases would matter little were it not that insistence on isolation as a first requirement often leads to the transfer of an ill child to hospital at a stage of the disease in which absolute rest is urgently necessary. Further, if transfer to an isolation hospital is insisted upon, this many involve transfer to a hospital which is inadequately staffed to deal with the possible complications which may develop with such frightening suddenness

There seems to be every reason to suppose that "typhoid precautions" in handling the patient provide protection to contacts, and having provided for these the physician need consider only the patient's interest as regards the desirability of transfer to hospital or as regards the choice of hospital in which he should be treated.

The W.H.O. Report No. 81 (1954) says of this: "When conditions permit, isolation of the patient in his home should be considered. If the patient is removed from his home it should be to a hospital or unit for infectious diseases, a special hospital for poliomyelitis patients, or an isolation unit (one or more rooms) in a general hospital"

This important matter is considered further in Chapter VI (p 56).

Other Control Methods

As the virus is usually ingested and is commonly found in the stools of healthy carriers, hand hygiene and protection of food is specially important.

The disturbing effect of certain operations and injections on the development of the disease will be referred to later.

Passive immunization with gamma-globulin is probably worth the trouble involved, thousands of persons have to be inoculated for one to benefit in any way, and protection only lasts for a few weeks.

Active immunization

The development of a safe prophylactic vaccine is eagerly awaited, and the prospects for this type of protection being available on a large scale are reasonably good. Two methods are being employed One which is associated with the name of Salk (1953, 1954) is already undergoing extensive trials, and consists of injecting a vaccine prepared from inactivated virus The other method which is more hopeful is the development of a safe attenuated living virus which can be given by the oral route. The names of Koprowski (1953, 1954) and Sabin (1955) are specially associated with this method (see also p 137)

The identification of non-immune individuals

Modern methods of growing the viruses in tissue culture make it possible to assess the immunological state of the individual, and this in the writer's opinion should be widely used in order to identify those children who are vulnerable, so that minor illnesses may be treated more carefully, and so that the need for protective active immunization may be assessed more clearly. A surprising development of this work is the utilization of cancer cells from carcinoma of the cervix as a tissue culture on which to grow the virus.

CHAPTER III

CLINICAL FEATURES OF THE DISEASE

"Major" and "Minor" illness

In its best-known form poliomyelitis consists of an acute disease with symptoms of meningitis (*the meningitic or preparalytic stage*) in which after one or two days paralysis develops (*paralytic* stage). In order to avoid ambiguity, Horstmann (1950) has advised that the term *major illness* (Fig. 5) be used for this, the principal stage of the disease. As will be emphasized later, the major illness generally begins abruptly, and this mode of onset is referred to here as a "typical" case, but in a proportion of cases there is a preliminary period of malaise and minor symptoms (prodromata) which hardly justify separation from the major illness, and this group is referred to as being "atypical" cases (see case histories).

The term *minor illness* is used to refer to a slight catarrhal reaction which occurs in about 40 per cent of paralytic cases a few days before the major illness begins. This minor illness is of great interest to the virologist, but few clinicians pay much attention to it. Usually the patient feels well between the two stages of the disease.

The Minor Illness

This minor illness is often a slight affair, and indeed it can only be recognized with confidence in retrospect when it is followed within three to seven days by the major illness (Fig 5). It generally lasts for 24 to 48 hours, and consists of non-specific symptoms such as fever, sore throat, headache, anorexia, vomiting, constipation, and muscle or abdominal pain

The minor illness is probably due to invasion of the blood stream by the virus; indeed, Horstmann and McCollum (1953) have isolated the virus from the blood in human cases during the minor illness and also in asymptomatic infections. Horstmann (1952) had previously demonstrated the virus in the blood of monkeys after infection via the alimentary canal. In a few cases

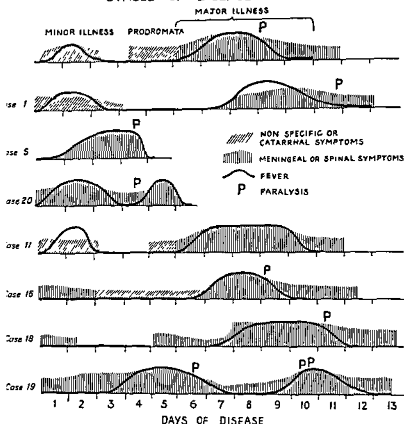


FIG 5 —Diagram to show various patterns which the disease may take, and the terms used to describe the stages of the disease

the symptoms of the minor illness have neurological characteristics (see cases 2 and 16), which suggest that the virus is already in the cells of the spinal cord at that stage.

The case records described in the following pages emphasize the great variety of clinical manifestations which may occur. Fig 5 indicates diagrammatically some patterns which the disease may adopt While there are often recognizable stages in the

clinical developments, these may be masked by unusual feat
some of which suggest that the virus-cell struggle has been g
on for some days before recognizable symptoms appear.
others there is the suggestion that what would have beer
abortive infection was converted to a paralytic form by sp
circumstances.

Abortive cases are those in which a minor illness occurs,
nothing more. Scores of these no doubt occur for every
which progresses to the major illness, but their identification
rarely be made with much certainty. In addition there
evidently countless asymptomatic infections, in which the v
presumably remains harmlessly in the wall of the alimen
canal yet providentially is able to encourage the developmen
antibodies (Koprowski *et al*, 1953). It is through the applicat
of this observation that the development of protective vacci
is likely to depend

As far as the frank clinical manifestations are concerned,
following short case records are used to present the variety
clinical features

Short minor illness in a "typical" case

CASE 1 (2).* Schoolgirl, aged 17 *Days 1 and 2 :* Sore throat w
slight anorexia Continued to attend school. Days 3–7 : Felt we
school as usual. *Day 8 .* Lumbar pain ; continued school *Day*
Lumbar pain less severe in the forenoon. Ballet-dancing for 1½ hou
[illegible] spreading to abdomen. *Day 1*
[illegible] Some nausea. Motor
[illegible] , less severe, but some pa
[illegible] Trunk muscles becar
[illegible] thighs and left arm.
Three months later there was severe paralysis of the abdominal ar
trunk muscles

The occasional appearance of neurological symptoms in th
prodromal stage is *of special interest, as they suggest son*
invasion of the central nervous system by the virus even at th
early stage.

Neurological symptoms as prodromata to major illness or possibly as part of a minor illness

CASE 2 (64). Female, aged 38 *Days 1–3 .* Hyperæsthesia of ski
of the abdomen. *Day 4 ·* Hyperæsthesia continued , she *felt wel*

* The case notes are numbered *seriatim* and also according to the author' records

and did an exceptionally heavy day's work in the house. *Day 5:* Acute onset of pain in head and back, fever (102° F = 38 9° C.) and irritability, continued housework all day *Day 6*. Symptoms continued Stayed in bed for half the day. *Day 7* · Left leg became paralysed

A month later there was still severe paralysis of the left thigh and trunk muscles (see also case 16).

YTIC
when it
rve cells
angerous
w hours,
Spinal
panied by
ne, trunk
ue, while
id shows
toms are
e appear-
of these
is may be
ble. The
s studied
eferred to
ical" are
prodromal
ome cases
in interval
ring which
rst of the
are often

alysis, and
ity This
Unfor-
beginning
ospinal fluid
develop severe
paralysis

A probable case of severe major illness without paralysis

CASE 3 (28). Schoolboy, aged 12. No prodromal symptoms. *Day 1:* Slight headache on waking, but he went to school and played football. That evening he developed severe headache and spinal pains in the dorsal and cervical regions. He vomited and was restless and sleepless that night. *Day 2:* The symptoms continued. His neck was stiff and his temperature 100° F. (37·8° C.). His body and all his limbs were painful. He was admitted to hospital. *Day 3:* The cerebrospinal fluid contained 73 cells per c.mm. and 45 mg. of protein per 100 ml. Complete recovery ensued without paralysis.

In the Paralytic Group, paralysis of some muscles generally appears after 1 to 5 days, progresses for 1 to 3 days, remains stationary for 1 week, and then slowly improves. Improvement continues for 6 to 12 months, or longer if the methods of early rehabilitation have not been very energetic.

As has been pointed out, the onset of the major illness is the most critical period of the illness, and it is only in this stage that any successful attempt can be made to recognize the disease before the onset of paralysis. Spinal or meningeal pains are especially important in diagnosis: they were reported in 95 of the 100 cases, and are analysed in Table I. This table shows that though

TABLE I

Analysis of the spinal or meningeal pains as they appeared in the 95 cases which reporte[d] these pains during the pre-paralytic stage

Pains in	Head	Neck	Back (lumbar or dorsal)	Back (sacral)	Shoulders or scapular region	Chest or abdomen	Thighs or legs
Head	64	40	32	8	11	15	15
Neck		57	27	10	9	12	15
Back (lumbar or dorsal)			52	11	7	12	18
Back (sacral)				23	4	9	11
Shoulders or scapular region					13	4	4
Chest or abdomen						24	15
Thighs or legs							31

several types of spinal pain are common, no one of them appears in more than two-thirds of the cases. The importance of these pains was emphasized in the classical work of Peabody, Draper and Dochez (1912).

Pains in the head

There is nothing specific about the headache when it occurs except that it is rarely intolerable, as it may be, for example, in bacterial meningitis it may consist more of a soreness at the back of the head which is part of a spinal neck pain. Pain in the head appeared on the first day of the pre-paralytic stage in 45 of the 100 cases. In a few instances severe throbbing frontal pain was reported, but generally the headache was relatively insignificant Study of the head pains may be of value in differential diagnosis, in that a patient who has spinal rigidity without severe headache is unlikely to be suffering from bacterial meningitis Occasionally pain in the head may appear without any of the more common spinal pains, as in the following case. This record also provides an example of an atypical case in which the onset of the major illness was vague and indefinite

Indefinite onset of major illness with fever and headache but no spinal pains

CASE 4 (39) Male student, aged 19 *Days 1–3* · General malaise, felt progressively more " fed-up ". *Day 4*. Went for a cross-country run (four miles) to try to " work off " his malaise He did not run easily, getting home with a struggle *Day 5* Attended lectures, no marked symptoms *Day 6* Fever and headache Walked with

Paralysis was almost complete and permanent in both lower limbs and lower trunk

Spinal pains

The spinal pains and paræsthesiæ provide by far the most characteristic clinical features of the pre-paralytic stage in patients who are old enough to describe their symptoms They were reported in 95 out of 100 such cases studied They often present features which are highly specific and of considerable interest. The severity of these pains varies greatly, as the following examples show They are often localized, and many have a segmental distribution The severity of the pain bears no relation to the severity of ultimate paralysis, but the *site* of pain at the onset of the pre-paralytic stage often corresponds to the site of maximum paralysis For example, in the present series there were

15 cases of paralytic poliomyelitis in which pains in the thighs occurred on the first day of the pre-paralytic stage. In all but one of these, a bulbar case, the paralysis was maximum in, or more often confined to, the lower limbs.

Severe spinal pain preceding severe paralysis

CASE 5 (50). Lieutenant in the R.N.V.R., aged 23. *Day 1:* After normal duties as a barrack guard officer and a little cricket practice he developed pain in the neck at about 6 p.m. He slept badly that night. *Day 2:* The pain in the neck became more severe, and in addition he developed severe sacral pain. This latter symptom made it impossible for him to rest in comfort. The buttocks were hyperæsthetic, so that he could not bear to sit or lie on his back. He went by car to report sick, but his back was so stiff that he had difficulty in getting into the car. He returned to his billet and went to bed, but could not rest; he got out of bed every hour or so to walk about for ten [illegible] epless
[illegible] tempt
[illegible]. He
[illegible] were
[illegible] per-
[illegible] kness
[illegible] very
slightly affected.

Severe spinal pain preceding slight paralysis

CASE 6 (25). Housewife, aged 30. *Day 1.* Usual household duties. She felt very tired after a half-hour walk in the afternoon. In the evening she developed sacral pain and also a pain in the right lower abdomen when walking. *Day 2: She stayed in bed.* The [illegible] became severe and caused great restlessness. Pain in the [illegible] cervical
[illegible], which
[illegible] The rest-
lessness also made her feel she would like to get up and move about *Day 4:* No change *Day 5* Pains less severe, but there developed paresis of the trunk, left thigh and left leg muscles. Satisfactory recovery occurred during convalescence in all the affected muscles

A history of *pain in the neck* is difficult to distinguish from stiffness, and the symptom is often more accurately described as a painful stiffness

Neck pain in the major illness causing difficulty with diagnosis

CASE 7 (35). *Male cinema operator, aged 16. Day 1:* Slight headache in the morning Work as usual About 8 p.m. there

developed aching pain in the neck which made him disinclined to move his head *Day 2*. After sleeping badly the pain in the neck continued; headache returned with some pain in the scapular region. Some vomiting and anorexia also occurred. He rested at home, and went to a

Six weeks later there was still paralysis of the muscles supplied by the upper dorsal cord, especially the intercostals. The limbs were not affected

Neck pain and stiffness in pre-paralytic phase followed by paralysis of neck muscles

CASE 8 (7) Schoolgirl, aged 11 *Day 1* · Developed pain and

school as usual *Day 5* · Stayed in bed, and this relieved the neck pain *Day 6* · Paralysis of neck muscles.

A month later there was almost complete paralysis of neck muscles no weakness elsewhere.

Pains in chest, abdomen or thighs

Pains in the chest and abdomen may cause considerable diagnostic difficulty Some characteristics which these pains may exhibit are apparent in the following records

Pain in chest as the principal early pre-paralytic symptom

CASE 9 (10) Male surveyor, aged 43 *Day 1* · Having suffered from a sore throat for the previous eight days, he now developed a girdle sensation around his chest, which became tender to touch. *Day 2* Chest pain continued, with fever, restlessness and sleeplessness *Day 3* Vomiting and anorexia also experienced *Day 4*. Pain in back and legs added to symptoms Developed weakness of the right arm, trunk muscles and right thigh

Ten days later the muscular weakness was slight and recovering rapidly.

Pain in chest as an early pre-paralytic symptom

CASE 10 (34). A nurse, aged 21, who had been nursing cases of poliomyelitis (night duty) for a month. *Day 1:* About midday she developed bilateral chest pain, which was aggravated by a deep breath and

of be

sent

by severe frontal aching pain in the head and later by severe sacral pain, both of which continued for three weeks after paresis developed. *Day 3:* Pain in the front of thighs on moving. *Day 4:* Neck stiff. Weakness developed in left arm, trunk, left thigh and left leg.

All the affected muscles recovered well within two months.

Severe abdominal pain as a pre-paralytic symptom

CASE 11 (5). Schoolgirl, aged 10. *Day 1:* Sent home from school with sore throat, fever and headache. Went to bed. *Day 3:* Felt well.

[illegible]

appeared, but this was not severe, and had largely recovered within three weeks.

Pain in trunk on movement as a pre-paralytic symptom

CASE 12 (3) Male machinist, aged 25. *Day 1:* Slight stiffness in back and pain in the head. Did a heavy day's work. *Day 2:* Ditto *Day 3*. Headache worse, and severe pain developed in thighs and a sharp pain in the left side of the chest each time he stepped forward with the left leg. Left leg also ached *Day 4:* Vomiting added to the above symptoms Weakness of abdominal muscles developed. *Day 5:* Pains ceased, but weakness spread to the thighs and legs.

A month later the left quadriceps was completely paralysed; all the other muscles affected were improving

Discomfort in chest and abdominal pain as pre-paralytic symptoms

CASE 13 (44) Schoolboy, aged 16. *Day 1* · Feeling of constriction in the chest on taking a deep breath. Ran 100 yards race *Day 2* · Pain in right iliac region on bending while playing a rackets match *Day 3* Above symptoms continued; some malaise. Ran a half-mile race not so well as he expected *Day 4:* Severe headache and pain in neck developed; fever, restlessness and sleeplessness. School in morning Tennis for half an hour; then reported sick for the first time and was sent to bed That night he developed rapidly spreading severe paralysis, especially of lower limbs and trunk A respirator was required for two weeks

The permanent disability in this case was severe.

Pain in thighs as a pre-paralytic symptom

CASE 14 (48) Accountant, aged 27 *Days 1–4*. Malaise and slight fever *Day 5*. Office work as usual. Slight sore throat;

lower limbs was permanent

Spinal paræsthesia as an early symptom

CASE 15 (45). Female clerk, aged 29 *Day 1* · Nasal catarrh for past six days Now developed pain in the back of the neck and a sensation like " cold water running down the spine ". Work in office as usual *Day 2* Same symptoms, with vomiting and fever in addition Rest at home, but she went out to visit doctor. *Day 3:* Symptoms less severe, resting at home *Day 4* Felt well, no pain now, but weakness of left arm developed

A month later the left deltoid was still completely paralysed, but other affected muscles were recovering slowly

Other pre-paralytic symptoms

Vertigo and a visual abnormality due to jerky movements of the eyes may appear early in the pre-paralytic phase when, as Bodian (1948) has shown, the virus is already in the brain stem Vomiting is common but seldom severe It was reported in 29 of the 100 cases

Nasal discharge, sore throat, diarrhœa or constipation may occur in the pre-paralytic phase but, being non-specific, these symptoms are usually of little value in early diagnosis.

Variations in mode of onset of major illness

Several variations in the course of the disease occur which are most easily described by brief case reports In some instances it is difficult to ascertain whether or not the minor illness is merging with the pre-paralytic stage

In the pre-paralytic stage of " typical " cases spinal symptoms usually become increasingly severe for two or three days, after which time paralysis appears and the spinal symptoms often

subside quickly. In some cases, however, the course of the pre-paralytic stage is erratic and may consist of two or more phases, as in the following examples.

CASE 16 (68). Schoolboy, aged 12, attending a Scout camp *Day 1:* Frontal headache and a pain over the anterior aspects of both thighs—"like a wire brush being pressed into the flesh". Tired and sleepy. *Days 2 and 3:* Felt well, but noticed that running about brought back the pain in his head and thighs. Took part in all camp activities. *Day 4:* Returned home, but still felt unusually tired. Average physical activity *Day 7:* Severe pains developed in head, thighs and knees. He went to bed early, but was awakened at 9 p m. by a nightmare to find the pains were worse than ever, and there was also abdominal pain. *Day 8:* Pains continued. Vomiting, retention of urine and fever—101·4° F. (38 5° C). Severe paralysis of the left leg and thigh developed.

CASE 17 (6) Schoolboy, aged 12 *Day 1:* Pain in back of neck and back of knees, malaise and shivery feeling. Fever about 101° F. (38·3° C). In bed for two days *Day 3:* Got up but pyrexia returned. Again in bed for four days *Days 10–14:* Living very quietly at home. *Day 16* Resumed school. *Day 18:* Played rugby football match. *Day 19 (evening):* Headache and slight vomiting. Temperature 100° F. (37 8° C.). Went to bed. *Day 20* · Developed pain in back of neck *Day 21*. Pains worse; also pain in dorsal spine. Girdle [illegible] The cerebrospinal fluid contained [illegible] ielial cells per c mm, [illegible] *Day 22:* Symptoms [illegible] paralysis developed

CASE 18 (79). Housewife, aged 30, two months pregnant. *Day 1*. Mild neck stiffness *Days 2–4* · Felt well; usual housework. [illegible] of pregnancy [illegible] d *Day 8:* [illegible] ere was also [illegible] Tempera- [illegible] continued [illegible] *Day 10* Cerebrospinal fluid contained 124 polymorphs and 117 lymphocytes per c mm, and 75 mg of protein per 100 ml. *Day 11* · Paralysis of lower limbs, trunk and diaphragm Respirator required This patient died later of pulmonary collapse

Relapsing cases. Spread of paralysis in two phases

In perhaps 2 or 3 per cent of paralytic cases a second phase of spreading paralysis occurs 3 or 4 days after the first paralytic phase. This happening is most disconcerting to the physician.

as it occurs just when the extent of the main paralytic phase has become manifest It is for fear of this relapsing type that strict rest is insisted on during the 2 weeks after the appearance of paralysis.

CASE 19 (1) Housewife, aged 33. *Day 1* · Developed neck pain in the evening *Day 2* Pains also in both shoulders. Some housework *Day 3* Pains worse. Severe headache, restlessness, sleeplessness and fever Got up and went to see a doctor *Days 4 and 5* · Symptoms continued *Day 6* · Paralysis of right shoulder and arm. Symptoms subsided. *Days 7 and 8* . Felt well, but was restless *Day 9* Improvement continued Got up to have bed made, malaise and vomiting that evening *Day 10* Paralysis spread to involve right thigh, right leg and right intercostal muscles.

Another remarkable feature of the pre-paralytic stage occasionally observed is that the patient's symptoms may appear to be abating at the time the paralysis develops

Abrupt onset of pre-paralytic phase Symptoms subjectively subsiding when paralysis of nearly all muscles developed

CASE 20 (29) Female factory-worker, aged 21. *Day 1* Wakened with pain in the neck, back and head Worked all day in the factory, the journey to work involved travelling for an hour each way She vomited and noticed something peculiar about her eyes she thought she might be getting infantile paralysis *Day 2* . Slept well, but still had pain in the neck, back and head She got up and walked (15 minutes) home, went to bed, and took castor oil. *Day 3* Pains less

breathe without the repirator

Thieffry (1947) has also drawn attention to paralysis occurring in some cases after the fever of the pre-paralytic stage has returned to normal

ATYPICAL CASES

The cases which show no abrupt onset of the spinal or meningeal symptoms in the major illness may be conveniently

termed "atypical" cases or cases with prodromal symptoms There were 11 of this type among the 100 cases studied. In some instances the catarrhal symptoms of the minor illness merge into the spinal symptoms of the major illness without the usual interval (see case 9). The day of onset is also uncertain when the spinal symptoms are at first vague (see cases 4 and 13), or they may continue for so many days before paralysis develops that the pattern of the disease is altered.

Prolonged pre-paralytic stage of major illness with indefinite onset

CASE 21 (41). Housewife, aged 28. *Days 1 and 2:* Tenderness of lower ribs for two days; no pain. *Days 3 and 4:* Tenderness of upper abdomen for two days; no pain The right leg developed slight weakness which cleared in two weeks *Days 5–7:* Tenderness of lumbar spine for three days. Very light work. *Day 8:* Tender on the anterior aspect of the right leg for two days. Very light work *Day 9:* In the morning sacral pain and stiffness developed. In the evening slight jerks of the right leg occurred with some pain in the leg *Days 10 and 11:* Sacral pain continued and slight fever developed.

The sacral pain continued until *Day 17*. The neck was stiff on admission to hospital on *Day 13*. On *Day 15* the cerebrospinal fluid contained 115 cells per c.mm (10 per cent polymorphs) and 70 mg of protein per 100 ml.

CASE 22 (77). General practitioner, aged 38. *Day 1:* Malaise and headache in the evening *Day 2:* Rested at home. *Day 3:* Listless and shivery, resumed practice. *Day 4:* No change. *Day 5:* Strenuous walk over the hills to "shake off" his malaise. *Days 6 and 7:* Continued his practice, though symptoms persisted *Day 8:* Forced to go to bed with fever, severe frontal headache, and pain and stiffness of the neck. *Day 9:* Excruciating sacral pain added to symptoms *Day 10* Weakness of right arm and leg and, later, respiration *Day 11:* Respirator required, nearly all muscles paralysed. *Day 12:* Died.

Muscular fasciculation

The appearance of muscular fasciculation is a sign of the greatest value in diagnosis in the pre-paralytic phase of the major illness. The slight involuntary contractions of muscular units, closely resemble those seen in motor neurone disease, and may be due to spontaneous discharges from motoneurones which are being destroyed by the virus The movements are easily seen on inspecting the patient's uncovered limbs and trunk, and they

may be sufficient to cause slight flickering movements of the relaxed fingers. The appearance of this sign often indicates that paralysis will affect the muscles showing fasciculation within the next 24 hours, but so far as the writer has observed, paralysis may be either severe or very slight after the appearance of this fasciculation There is need for further study of this sign in relation to the subsequent paralysis.

Cerebral and Bulbar Cases

In most spinal forms of the disease, and in many bulbar cases also, consciousness is fully preserved, and this mental alertness often helps to distinguish poliomyelitis from other types of encephalitis, and from bacterial meningitis In some cases of poliomyelitis, however, the patient becomes drowsy or comatose, and this is an important type of case, for contrary to the alarming impression of this critical illness, such patients (usually children) make a remarkably complete clinical recovery if they can be kept alive for the first two or three weeks of the disease.

All cases of poliomyelitis show histological changes in the brain also, but these are rarely of such a nature as to cause death in themselves, provided that any respiratory insufficiency is properly handled In some cases of polioencephalitis, however, there may be early and severe loss of consciousness with mid-brain involvement which may also cause palsies of conjugate eye movements, nystagmus and ataxia. These cases may require virus studies to establish the true ætiology, but sometimes the development of a spinal or cranial nerve palsy provides important evidence that the poliomyelitis viruses are responsible. Thus, the appearance of paralysis of one or more of the motor cranial nerves is often highly significant in such a case. Irregularity of respiration due to involvement of the respiratory centre may cause anxiety, even though there is no paralysis of the muscles of respiration Vomiting and true vertigo may also occur. As will be emphasized later, vomiting is extremely dangerous when swallowing is paralysed or if the patient is in a respirator, for in either case the vomit is liable to be inhaled into the lungs

The case records which follow illustrate some of the difficulties and dangers which have to be dealt with.

Bulbar Poliomyelitis following tonsillectomy, prolonged unconsciousness and respiratory irregularity, treated with postural drainage Recovery

CASE 35 (S. 4721). Female, aged 5 years. Tonsillectomy nine days before day 1. *Day 1:* Headache and listless *Days 2–4:* Remained "off-colour". *Day 5:* Vomited repeatedly, refused food and developed pain and stiffness in back of neck. *Day 6:* Voice became indistinct and had difficulty with swallowing and breathing Admitted to hospital. On arrival at hospital she was cyanosed and unconscious · postural drainage was established in the ambulance to clear the airways of secretions, and consciousness returned partly in ten minutes. She remained very drowsy and mucus drained freely



FIG 6.—Facial paralysis after bulbar poliomyelitis.

from her mouth There was strabismus, nystagmus, left facial paralysis and paralysis of the pharynx, larynx and sternomastoids. All four limbs were seen to move The diaphragm movement was weak but the intercostals were strong The respirations were markedly irregular. C.S.F. 42 cells per c.mm, and 25 mg of protein per 100 ml Oximeter readings varied from 90–95 per cent [illegible] shoulder, otherwise she made a good recovery, but she wore a sponge rubber collar for many weeks to support her head There was a slight tendency to mental irritability when seen a year later, but the physical condition was satisfactory

Note. This was a long and anxious battle. The prolonged uncon-

sciousness and irregularity of respiration (Biot type with periods of apnœa for ½ minute), caused much anxiety lest a dangerous state of hypoxia was the cause of the unconsciousness However, the oximeter readings and the biochemical estimations were adequate, so in the end neither tracheotomy nor artificial respiration was needed. Preparations were always at hand to do a tracheotomy should it prove to be necessary.

Severe bulbo-spinal poliomyelitis treated with postural drainage Some dangerous choking attacks Recovery

CASE 36 (S. 4719) Female, aged 16 *Day 1* · sore throat. *Day 2* · fever, headaches and limb pains. *Days 4–6* : Listless but at school On *Day 6* she developed headache, nasal voice and vomited, and was admitted to hospital The C S F. was normal and she was given diphtheria antitoxin, a throat swab was negative *Day 7* · [illegible]

a choking attack with cyanosis, the airways were cleared by suction and posturing Signs of broncho-pneumonia developed with a rise of temperature to 103° F *Day 11* Still unable to swallow, and there was weakness of the left deltoid and nystagmus on looking to right and left *Day 12* Dangerous choking attack after vomiting with cyanosis and loss of consciousness for 4 minutes Respiration stopped, but started again after suction through a laryngoscope *Day 14* Swallowed a little *Day 16* · Swallowing very little, tube feeding by nasal catheter was started and was continued to *Day 20* *Day 35* · Can now swallow effectively but an occasional tendency to choke continued [illegible]

shorthand typist No dysphagia, voice normal but slight facial asymmetry persists with moderate weakness of sternomastoid and the left deltoid

Note For over two weeks this patient was never left alone and a half-hourly report of her condition was recorded The choking attacks did not occur while lying in the prone or semi-prone position The lateral posture with raising of the foot of the bed was much used, as the patient complained of great discomfort in other positions The rectal [illegible]

Bulbar poliomyelitis treated with postural drainage. Recovery

CASE 37 (R.I.N. 6389). A female, aged 13. *Day 1 :* Nausea, vomiting and dizziness (9 days previously had a severe pain in her chin on the left side). *Days 2–3 :* Increasing difficulty in swallowing and speaking. *Day 4 :* Retention of urine and double vision. Drowsy but would answer questions. Denied headache, but there was severe neck stiffness. There was also continual nystagmus, left-sided ptosis and paralysis of the left face, the palate and the pharynx. C.S.F.: Protein : 80 mg. per 100 ml., cells : 21 per c.mm. Patient was nursed almost continually in the prone position with the foot of the bed also raised at times. Fluids were given by intravenous drip. Auscultation over the trachea was used to indicate when suction was required. *Day 5 :* Less conscious, slept most of the day. *Day 6 :* Oximeter reading 95 per cent. *Day 7 :* Able to talk a little but delirious. *Day 8 :* Can cough a little. *Day 9 :* Able to swallow and talk. *Day 30 :* Excellent recovery except for paralysis of the left face and weakness of the sternomastoids.

Fatal bulbar poliomyelitis

CASE 38 (S. 3655). A boy aged 8 years. *Days 1–3 :* He had a mild "*cold*" *which cleared rapidly. Day 7 : Attended school,* but vomiting in the afternoon and evening. *Day 8 :* Anorexia and vomited twice, he sat in a chair all day. *Day 9 :* Difficulty with swallowing and speech developed along with some headache and neck pain. *Admitted to hospital, where he was found to have neck stiffness,* diplopia due to lateral rectus weakness, left facial palsy, paresis o[f] swallowing, and speech. Limbs, trunk and respiration were unaffected. C.S.F. 120 cells per c.mm (20 per cent polymorphs) and 75 mg *of protein per 100 ml.* Transferred to another hospital at 8.30 p.m. where he arrived conscious but restless; respirations were irregula[r] but not paralysed. Postural drainage was established in the pron[e] position and abundant secretions flowed from his mouth. 11.0 p.m. the child was restless but conscious. Respirations were now 30 pe[r] min. *Day 10 :* 1.30 a.m. Temperature—99·2° F., Pulse—112 pe[r] min.; Respiration—38 per min. but irregular. Colour good. Con[-]scious but restless. 4 a.m., sudden collapse with cyanosis, recta[l] [illegible] per min. Respiratio[n] [illegible] Air passages dry [illegible] as put in a respira-

[illegible]

At post-mortem examination, the respiratory passages were clear. The brain was grossly œdematous, due no doubt to the steeply maintained postural drainage after the collapse at 4 a.m. There was severe [illegible] in the upper cervical spinal cord and brain stem. [illegible] cts of doing [illegible] *admission* to [illegible] post-mortem

probably did not contribute to death, but was rather a consequence of the circulatory collapse. However, the tendency to œdema in these [illegible]

just in case there had been a slowly developing hypoxia due not to paralysis of the respiratory muscles but to inflammation of the respiratory centre. However, this patient died in April, 1953, before intermittent positive pressure was organized in this country. Nor was an oximeter available to control progress

Bulbar poliomyelitis Inhalation of vomit while being nursed in supine position caused fatal hæmorrhagic necrosis of the lungs

* Case 39 (R I 180349) A schoolgirl, aged 13, developed pyrexia (100° F) and felt " a lump in her throat " Her appetite was poor, but she ate and drank at all meals. Two days later she drank about 10 oz. at breakfast with some difficulty and thereafter developed complete paralysis of swallowing. She was admitted to another hospital that evening and was found to have, besides dysphagia, weakness of the left face, the palate, the sternomastoid muscles, and the muscles of the shoulder girdles and upper arms. Anterior poliomyelitis was diagnosed

Next morning she had a cyanotic attack which rendered her tem- [illegible]

min She was receiving 100 per cent oxygen through a mask, and her colour was satisfactory, but her ventilation was manifestly too small to prevent retention of carbon dioxide

A cuffed endotracheal tube was introduced and respiration maintained with an Oxford inflator The patient was transferred in this way by ambulance to the Radcliffe Infirmary, a journey of some fifty minutes During the journey she began to move her limbs and to open her eyes when told to do so

On admission bronchoscopy was performed, but no considerable amount of inhaled material was within reach It was thought that when she recovered from the effects of under-ventilation she might be able to breathe spontaneously An endotracheal tube was therefore replaced, and positive-pressure respiration was instituted down this tube from Radcliffe respiration pump A.

Next day an attempt was made to let her breathe spontaneously,

* Case 2 from paper by Crampton-Smith *et al* (1954)

but she could not. A formal tracheotomy was therefore done and I.P.P. respiration continued with Radcliffe respiration pump A Two hours later, twenty-two hours after I.P.P. respiration was begun, her blood-pressure dropped to 40 mm. Hg systolic, her nail-beds and subsequently her lips became deeply cyanosed, and she died

Radiography of the chest on admission had showed mottled shadowing throughout the lung fields

Necropsy findings. The diagnosis of anterior poliomyelitis was confirmed. The endotracheal tube had been in position for twenty hours, and there was considerable ulceration of the larynx. An intense hæmorrhagic consolidation involved about five-sixths of the lungs, and the relatively normal fifth was situated anteriorly. Presumably this hopeless state of the lungs was a consequence of secretions, and perhaps vomit, being inhaled on the day before death.

The term *bulbar poliomyelitis* is used in different ways; to indicate perhaps that the eye movements, the muscles of mastication or of the face are affected; or that the breathing and blood pressure control are disturbed. It is perhaps expedient, however, from the clinical point of view, to use the term bulbar poliomyelitis, especially for those patients who, whatever other lesions occur, develop paralysis of the palate, pharynx or larynx Paralysis of swallowing demands the introduction of a highly specialized form of treatment, and some convenient term is required which indicates the urgent need for special action in these cases

It might have been anticipated that paralysis of swallowing would be easy to recognize clinically, but mistakes are all too frequent, especially in children whose only obvious symptom may be a stubborn refusal to eat or drink. Drowsiness or coma may be associated with paralysis of swallowing, and when this occurs the comatose state is the obvious feature, and the pool of mucus in the throat is thought to indicate the "death-rattle" of impending dissolution, which indeed it does if the doctor fails to drain the pharynx and trachea by turning the child on his face, raising the foot of the bed and manually compressing the chest to assist expiration. *It cannot be emphasized too strongly that it is extremely dangerous to nurse patients who are either comatose or have paralysis of swallowing lying supine (on their backs)*

The symptoms of respiratory insufficiency are considered on p 71

Sphincter control

Retention of urine may develop during the pre-paralytic phase, and sometimes provides an important warning that paralysis of the lower limbs will follow within a few hours This sphincter difficulty is probably never permanent in poliomyelitis, and its treatment will be considered later.

Summary of meningitic, spinal cord and brain stem symptoms

Though the pre-paralytic symptoms in the spinal forms of the disease are varied, these case histories have something in common. The symptoms for the most part suggest either meningitic or myelitic lesions, sometimes flitting from one part to another, and sometimes without any serious feeling of illness It may therefore be maintained that the pre-paralytic phase of the major illness generally presents with a variety of symptoms which, when analysed in regard to their features and time-relationships, often form a reasonably characteristic clinical picture

In this connection, however, it must be emphasized that the symptoms described above are only reported accurately by patients over the age of about 8 years In younger children the analysis of symptoms is of little value, especially where pain is concerned. Many infants fail to draw attention to lesions which are obviously painful, and this, no doubt, contributes to Horstmann's contention (1950) that pre-paralytic symptoms are less common in children than adults

The treacherous bulbar cases often also have meningeal symptoms, but the clinical picture is quickly dominated by paralysis of the throat or perhaps unconsciousness. Respiration is often adequate, but only if the lungs are kept healthy and the airways clear, and in this matter skilled treatment will save many lives (see p 69)

Duration of pre-paralytic phase of the major illness

As has already been pointed out, the variable duration of the pre-paralytic or meningitic phase suggests that in some cases there is a prolonged state of critical balance between recovery and paralysis Several of the above case records illustrate this

feature In 94 paralytic cases the day of the major illness on which paralysis developed was as follows: Days 1 and 2, 20 cases; day 3, 24 cases; day 4, 24 cases; day 5, 7 cases; day 6, 10 cases; day 10 or 11, 5 cases The decision as to what constitutes the onset of the major illness, however, is sometimes difficult to make. In case 16, for example (see above), the thigh pains on day 1 are thought to provide justification for considering this to be the onset of the pre-paralytic stage of the major illness Some, however, may consider this symptom of day 1 to be due to an unusual and severe form of the minor illness.

Hour of onset of major illness

As has already been pointed out, the onset of the major illness is usually quite abrupt. In 80 such cases the major illness began before 8 a.m. in 34 cases, between 8 a.m. and 4 p m. in 13 cases, and after 4 p.m. in 33 cases. The hour of onset is of importance when attempting to compare severity of paralysis with amount of physical activity after onset of the major illness Thus, when symptoms develop in the afternoon, the amount of physical activity taken during the forenoon of that day seems to be relatively unimportant, while physical activity continued in the hours actually following the onset of symptoms is very dangerous (see p. 47) Albrecht's (1951) study is open to criticism in this regard, for he apparently scorned the amount of physical activity on the day of onset of the disease irrespective of whether the symptoms began before or after the exercise taken.

CHAPTER IV

PHYSICAL EXAMINATION

IT has already been emphasized that the clinical history is often of special value in the diagnosis of poliomyelitis, especially in older patients Physical examination is, of course, vital also, and must be carefully planned to give the maximum information with the minimum of disturbance and fatigue to the patient Detailed muscle charts should never be prepared for the seriously ill child As with all sick children, observation of the child for a few minutes often gives information of the greatest value. The degree of consciousness, squint, spontaneous nystagmus, neck retraction, disinclination to move, facial paralysis, feeble cry or cough, diminished respiratory excursion, respiratory rattle due to a pool of mucus in the pharynx (in bulbar palsy), failure to move one or more limbs spontaneously, muscular fasciculations —these are among the abnormalities which may be detected by observation only

Spinal rigidity is an early sign of great importance, and inability of the child to kiss its knees is a popular and useful test for this stiffness Kernig's sign also becomes positive and the neck muscles are rigid

There is an art in detecting slight degrees of neck rigidity a good method of testing this is for the examiner to rest his elbows on the bed, one on each side of the patient, and then with this support to lift up the child's head gently with a movement of the fingers and wrists (Fig 7) In this manœuvre the movement can be carried out so gently that voluntary resistance by the patient can generally be avoided.

Examination of the nervous system

Clearly the amount of neurological examination during the pre-paralytic stage should be limited to bare necessities. However, two or three muscle groups can be examined roughly in each limb in a very short space of time, as also can the main



FIG 7.—Method of testing for neck rigidity

Note that the elbows of the examiner are supported while the head is flexed by a movement of the hands and fingers

trunk muscles It is improbable that there will be much weakness in a limb in which the tendon reflexes are still active Accurate muscle charting is quite out of place during the acute stage of the major illness, but sufficient examination is obviously necessary in order to recognize frank paralysis, and to follow the progress of the paralytic process The following simple tests will be found appropriate to many cases.

Mental state and general appearance. It has already been mentioned that most patients with poliomyelitis remain fully conscious, and never appear to be gravely ill as far as their general appearance is concerned. Toxic confusion is rare, but drowsiness and even coma may occur, and may then mask the signs of paralysis of the pharynx

The adult patient may become very hysterical, especially if breathing is becoming difficult, and this mental reaction has led to some very shocking mistakes in diagnosis As a part of the mental picture it may be mentioned that the intelligent adult often makes the correct diagnosis of his own case before his doctor does

The air passages and lungs. Obstruction to the air passages must be recognized by the first doctor to see the patient Listening to the breath sounds usually gives all information required, for the irregular and embarrassed efforts to breathe through mucus in the pharynx are extremely characteristic. The diagnosis of obstructed respiration is quickly confirmed by the dramatic relief which follows postural drainage (p. 69). Should collapse of a lung already have occurred the rapid and struggling respiration may suggest the diagnosis of pneumonia, and if the respiratory muscles are weakening exhaustion and collapse may develop quickly.

Trunk and respiration. Examination of the muscles of respiration is of special importance, as on this must depend decisions as to the need for respirator treatment either to maintain life or to rest weakening muscles (see p 91) If trunk muscles are paralysed, turning movements in bed become impossible, and the child is quite unable to sit up without support. The abdominal and spinal muscles are generally affected together, and the former is quickly tested by an attempt by the patient to lift his head forwards off the pillow, or to cough, while the examiner watches and palpates the abdominal muscles. Inability to raise the head may, of course, be due to paralysis of neck muscles, but this is easily recognized in the conscious child by gently raising his shoulders off the bed, when reflex maintenance of head posture will cause the neck flexors to contract if they can The head lolls backwards with this manœuvre when the neck muscles are paralysed If the cough or cry is very feeble, the abdominal muscles are probably already paralysed Deviation of the umbilicus (up, down or to one side) indicates segmental or one-sided weakness The abdominal muscles are of course *expiratory* muscles and not of such vital importance as are the muscles of *inspiration*, the most important of which are the intercostals and diaphragm

For the intercostals and diaphragm, inspection of the trunk during breath [illegible]

[illegible]

of tidal air with each breath; but a good test for respiratory failure, provided the larynx is not affected, is to ask the patient

to count rapidly, and to observe how far he can count in one breath. Counting to over 20 in one breath is easy for the normal person, and as respiratory paralysis develops, this drops to under 10, and even to under 3. There is much to be said, however, for taking actual measurements of tidal air and vital capacity in these patients with some form of spirometer (Bourdillon *et al*, 1950).

Gas meters are now available to take the place of the clumsy water spirometer, and if a mask with non-return valves is used

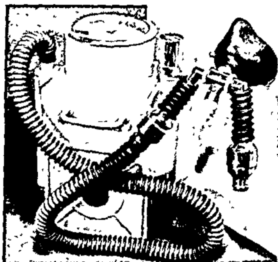


FIG 8 —Mask, one-way valves and gas meter to measure tidal air and vital capacity.

the patient is enabled to breathe comfortably through the meter for several breaths (Fig 8)

Such measurements, if taken at, say, hourly intervals, give ample warning of developing respiratory insufficiency due to paralysis, and many physicians introduce a period of respirator practice long before the weakness advances to a dangerous extent.

It should of course be appreciated that either paralysis of the throat or paralysis of the muscles of respiration may lead to a very similar picture of respiratory insufficiency; and *yet they must be distinguished from each other, as the appropriate treatments for the two conditions are quite different one from the other.*

There is, moreover, a third type of respiratory difficulty which may develop either from direct involvement of the respiratory centre by disease, or if respiratory insufficiency is not quickly treated, from the effects of anoxia on the respiratory centre. Finally, there may develop any combination of these various causes of respiratory insufficiency, so that the assessment of a complicated case may present great difficulties

The extremities

During the acute stage the strength of the extremities is examined for two chief reasons The first is to recognize gross paralysis if it appears, and the second is to follow the course of the paralytic process to the point where it stops getting any worse The muscles are examined during the major illness as little as possible, but a few tests should be carried out once or twice daily to ascertain the general distribution and severity of paralysis. In the infant, the mere act of lifting up a limb will stimulate various muscles to contract, and muscle groups which fail to contract are generally easily identified through watching and gently resisting the spontaneous movements of the limbs.

Upper limbs If the arms are held out against gravity even for a moment, the deltoid at least must be contracting. The main muscle groups can be resisted and tested in both arms at the same time if the patient can respond to instructions such as

- " Press your elbows down to your sides and hold them there " (shoulder-fixing muscles),
- " Pull your hands up to your face " (biceps),
- " Push my hands away " (triceps),
- " Squeeze my fingers hard " (forearm muscles);
- " Spread all your fingers out and don't let me press them in " (small muscles of hands)

Each movement is resisted by the examiner in order to estimate the degree of weakness if any

Lower limbs The lower limbs have to be examined one at a time, and it should be remembered that the weight of the limb interferes with muscle-group testing much more in the lower limb than in the upper During testing, therefore, the examiner will,

in cases with weakness, find it necessary to support the weight of the limb with one hand under the knee and one at the ankle, while he asks the patient to try as follows:

"Pull up your knee as much as possible" (thigh and knee flexors);
"Push your leg out straight" (thigh and knee extensors);
"Press your leg down towards the bed" (thigh extensors);
"Pull your toes towards you" (dorsiflexors);
"Push down" (plantar flexors).

In this sort of way the main muscle groups can be tested in a few minutes, and examination can often be adequately carried out even with the patient lying on his side. Examination may be greatly hindered by muscle tenderness, and may then have to be modified considerably.

Reflexes and sensation

A somewhat cursory examination of sensation will suffice unless, of course, there is any possibility of some other form of acute spinal disease as a cause of the paralysis.

In poliomyelitis there is no loss of sensation, while the muscles are often tender in all parts of the body. If tenderness is local the diagnosis is probably not poliomyelitis, and conditions such as osteomyelitis or septic arthritis should be considered. In poliomyelitis there is no true joint fixation by muscle spasm such as is seen in joint infections.

The tendon reflexes disappear as paralysis develops, and absent reflexes provide a valuable confirmation of genuine acute lower motor neurone paralysis The plantar response is absent or else generally flexor. The abdominal reflexes are absent if the abdominal muscles are weak.

Retention of urine is an important early symptom in some cases, so that bladder distension must not pass unobserved. Abdominal distension is sometimes troublesome, especially in cases being treated in tank-type respirators.

The Cerebrospinal Fluid (C.S F.). The changes in the cerebrospinal fluid are most helpful. The cerebrospinal fluid in the major illness is very rarely normal, but there may be only a slight increase of cells to, say, 20 per c.mm. with a negligible

increase in protein to 40 or 50 mg per 100 ml In some cases, however, there are 700–800 cells per c mm., 85 per cent of which are at first polymorphs, and many such cases are treated first as cases of *pyogenic meningitis*. However, the protein in these cases is relatively low (80–200 mg per 100 ml.), whereas in *pyogenic* or *tuberculous meningitis* the protein generally rises in proportion to the cell count

As paralysis develops the cells drop in number and become chiefly lymphocytes, while the protein rises (perhaps to over 500 mg per 100 ml) and remains high for several weeks

Differential Diagnosis

The correct and early diagnosis of intracranial infections was at one time of limited practical importance Now, however, with the development of specific treatment for several of these diseases, the early and accurate diagnosis of intracranial infections has become increasingly important, and throws a formidable burden of responsibility on the physicians and surgeons concerned

The rapid onset of spinal symptoms in the typical case of poliomyelitis has been described, and the remarkable preservation of full consciousness is often a striking feature Indeed, the absolute mental clarity in such cases excludes a host of grave intracranial infections whether encephalitic or meningitic Thus, mental irritability or confusion is usually an early sign of tuberculous meningitis

The meningitic symptoms or signs may be the same in many infections, but in poliomyelitis they are often relatively focal, and may at times be confusing in their vagueness There may, for example, be severe sacral pain without headache, paræsthesiæ in the thighs, or pain in the chest or trunk (resembling Bornholm disease)

The appearance of muscular fibrillation, and later of scattered lower motor neurone paralysis with muscle tenderness and sensitivity to movement, make the diagnosis of poliomyelitis quite certain

Difficulties arise when there is polioencephalitis with disturbed consciousness, but none of the frank local cranial nerve palsies

The recognition of early tuberculous meningitis may be very difficult when the changes in the C S F are not characteristic,

and when careful search for the tubercle bacillus in the C.S.F. is negative.

Recent work by Taylor *et al.* (1954) has shown that the blood-C.S.F. barrier for bromide breaks down very early in tuberculous meningitis, but not in virus infections such as poliomyelitis. This may, therefore, be used as a diagnostic test.

In considering other possible infections of the central nervous system, various forms of *virus encephalitis* and the *post-exanthematous encephalomyelopathy* may require consideration. *Mumps meningoencephalitis* is surprisingly common. *Epidemic pleurodynia* (Bornholm disease) may resemble poliomyelitis very closely. There is here often a curious chest pain and tenderness with fixity of the diaphragm, with recovery in 24 to 48 hours; but often one or more relapses occur. Limb muscles may also be involved.

Acute infective polyneuritis may closely resemble a rapidly spreading type of poliomyelitis, but the symmetrical spread to all muscles, including the face, with subjective sensory loss and a very high protein content in the cerebrospinal fluid without cells, distinguishes this disease on careful investigation. Every effort must be made to recognize these cases of acute polyneuritis, as they make a complete recovery if kept alive during the period of complete paralysis (often lasting 2–3 weeks). There is a serious danger that these may be looked on as hopeless cases of poliomyelitis, and may even on this account be denied the enormous effort required by those in charge to preserve life during the phase of severe paralysis (Crampton-Smith *et al.*, 1954).

Almost any condition which causes paralysis may, during an epidemic, be mistaken for poliomyelitis. Thus, *cerebral thrombosis* or *hæmorrhage*, *transverse myelitis* and *hysteria* should be mentioned.

Pressure palsies appear suddenly without associated illness, and lesions of specific peripheral nerves result. *Shoulder-girdle neuritis* (neuralgic amyotrophy) sometimes causes confusion. Severe pain in shoulder-girdle muscles is followed often after 3 or 4 days by flaccid paralysis (usually complete) of muscles supplied by one or more peripheral nerve or nerve root. The circumflex, the suprascapular, the long thoracic and the 5th

cervical root are the nerves most commonly affected The clinical course is quite distinct from the paralysis of poliomyelitis for it resembles the behaviour of the facial muscles in Bell's palsy or in a pressure palsy. The paralysis is often complete at first, but recovers either like a transient nerve block in 3 or 4 weeks, or laboriously by regeneration in 3 to 9 months—a process which never occurs in poliomyelitis.

Bell's palsy is usually distinguished without difficulty, for though facial paralysis may occur in poliomyelitis it is rarely quite as complete as is common in Bell's palsy and the course of recovery is again quite different, as it is in shoulder-girdle neuritis

Botulism, *rabies* and *local tetanus* should be mentioned in connection with diagnosis.

Another group of conditions which may cause difficulty in infants are those which cause a painful refusal to move a limb such as occurs in *osteomyelitis*, *acute infective arthritis* or in some form of *local injury*

Rigidity of the spine due to *extradural abscess* is specially important, as failure to provide surgical decompression is likely to lead to transverse myelitis

Lesions of the cervical spine, such as the rare, but dangerous subluxation of the odontoid process, cause neck stiffness of a different type, in that gentle rotation movements are also prevented, and an obvious distortion of neck posture is often apparent

When respiratory insufficiency or atelectasis develops it has already been pointed out that *primary pneumonia* may be diagnosed, and the hysterical reaction of the patient developing respiratory paralysis may lead to the disastrous mistake of thinking that the symptoms are psychogenic in origin

Finally, the patient with limb or trunk paresis often looks quite well and may be told he has *nothing the matter*, or perhaps some *rheumatism* In this connection the importance of knowing how to test the strength of muscle groups is obvious (see M R C. War Memorandum No 7).

CHAPTER V

FACTORS WHICH INFLUENCE CELL VULNERABILITY

IN studying the practical management of cases one naturally searches for factors which might decide which cases are likely to develop serious paralysis. Does one person become paralysed because he has less immunity to the virus than others similarly affected, or is his resistance influenced by some passing state of his own cell metabolism? A striking phenomenon in this latter connection was demonstrated by Howe and Bodian (1942), for they found that section of a nerve root shortly before experimental intracerebral infection with poliomyelitis virus gave the nerve cells supplying the sectioned roots complete protection from the virus On the other hand, Swartzmann (1950) and others have shown that cortisone enhances the effect of poliomyelitis infection in hamsters and mice.

It is now well known that viruses enter intimately into the metabolism of the host cell, so much so that the virus particles seem to disappear at certain stages of their intracellular development. Increasing attention is therefore being paid to the possibility of disturbing the cycle of virus multiplication by interfering with the metabolism of the host cell At the Second International Poliomyelitis Conference in Copenhagen Horsfall (1951) stated: " If the objective of interrupting virus multiplication by chemical means is to be attained, present evidence supports the idea that this will come about through substances which act on intracellular components, possibly in enzyme systems, rather than on the virus *per se* "

This field of research has been opened up very greatly by the discovery by Enders (1951) that poliomyelitis viruses can be grown on cultures of human embryonic tissues. Another promising field for research is provided by the study of bacteriophages which act as do viruses in relation to the bacteria they infect (Delbruck, 1951) These fields of research greatly increase the prospects of a method of treatment being found which can be used to arrest virus activity in the acute stage of the disease.

Thus Ainslie (1952) has been able to arrest the multiplication of polio virus by interfering with the Krebs metabolic cycle of the cell, while Sanders *et al.* (1953) have studied the effects of various neurotoxins such as the detoxicated venom of vipers. The possible clinical value of this work is now under investigation.

Physical activity after onset of the major illness Another clue to this problem is provided by a study of the apparent effect of physical activity on the course of the disease. In many epidemics there have been reports of an apparent association between great physical exertion and a rapidly following fatal paralysis, while Levinson, Milzer and Lewin (1945) provided some experimental confirmation The importance of this matter has been studied by a simple investigation. A series of convalescent patients was carefully questioned as to their activities before and after the onset of their symptoms, and a scoring system was used both for the amount of physical activity and for the severity of paralysis (Russell, 1947, 1949; Horstmann, 1950).

These investigations showed that the amount of exercise taken *prior* to the onset of the major illness (meningitic stage) bore no very definite relationship to the development of paralysis The story, however, was very different if the amount of physical activity taken *after* the onset of the major illness was compared with the severity of paralysis Not that a large proportion of severe cases indulged in great physical effort after the onset of

pared in Table II. It will be noted that the methods of scoring used are not identical in these two studies, and are therefore not exactly comparable

The author's figures are given in more detail in Tables III and IV In Table III, the days of the disease are numbered backwards from the day paralysis appeared (P-1, P-2, P-3 and P 4) The cases are divided into two groups · (1) slight paralysis —good recovery expected, (2) moderate or severe paralysis—permanent disability expected The proportion of cases in each group which continued physical activity during these four days is shown It is obvious that non-paralytic cases cannot be included in Table III

TABLE II

The effect of physical activity continued after the onset of the major illness on the development of moderate or severe paralysis

Dr. Horstmann's cases	Number developing paralysis (moderate, severe or fatal)
174 patients rested on first day of illness after onset of symptoms of major illness . .	62 (35 per cent)
173 patients did not rest on first day after onset of symptoms	133 (77 per cent)
Dr W R Russell's cases	
38 patients rested during the whole 24 hours following onset of major illness . .	8 (21 per cent)
51 patients did not rest during the whole of the 24 hours after onset . . .	43 (84 per cent)

TABLE III

Physical activity on the days preceding paralysis compared in cases developing (1) slight, (2) moderate or severe paralysis

Severity of paralysis	No of patients in each group who undertook moderate or severe physical activity during each of the four days preceding paralysis (P-1, P-2, P-3, P-4)			
	P-1	P-2	P-3	P-4
Slight (33 cases) .	0	6 (18%)	11 (33%)	18 (54%)
Moderate or severe (59 cases)	14 (23%)	35 (59%)	51 (86%)	53 (90%)

TABLE IV

Comparison in "typical" cases only, between the severity of paralysis and the amount of physical activity after the onset of the pre-paralytic stage

Amount of physical activity after onset of pre-paralytic stage	Permanent paralysis		
	Slight or none	Moderate	Severe or fatal
Nil or slight for less than 24 hours	30	6	2
Moderate or severe for less than 24 hours	6	9	7
Slight, moderate or severe for more than 24 hours	2	12	15
Totals	38	27	24

Another method of investigating this matter is by numbering the days of the disease from the onset of the pre-paralytic stage; but this can only be done in the "typical" cases with an abrupt

onset of spinal symptoms. In Table IV the ultimate severity of paralysis in the typical cases is compared with the amount of exercise continued after the start of the major illness.

These figures indicate that physical activity during these critical hours of the meningitic stage has a profound and most alarming influence on the course of the disease. Modern histological techniques can demonstrate changes in the motor cell after exercise (Hyden, 1943), but why this should facilitate the virus in its ability to destroy the nerve cell is quite unknown. However, we must clutch at this clue to virus behaviour and pursue research on factors which influence cell vulnerability to viruses, and it may be noted that physical activity no doubt alters those intracellular components, the importance of which Horsfall emphasizes in relation to those factors which influence virus multiplication.

These studies were made on the spinal type of case and could only include patients old enough to give a good account of their symptoms (over 7 or 8 years of age). As Horstmann found, the bulbar cases seem not to be influenced by physical activity to any demonstrable extent. The effects of tonsillectomy are considered later.

Exercise before the major illness. The above investigations showed clearly that the continuing of ordinary physical activity *after* the onset of the meningitic phase is dangerous and that complete rest is protective. The possible harmful effect of excessive exercise *before* the onset of meningitic symptoms cannot, however, be ignored. There are many records of the major illness following within 12 or 24 hours of some unusually strenuous form of exercise. This suggests either that the major illness has already begun during the period of exercise without its being noticed, or else that the excessive exercise may sometimes force the development of a major illness on a case which would otherwise have been abortive.

Cases in which special physical activity after a short minor illness was followed within 24 hours by acute spinal symptoms of the major illness and later by paralysis

CASE 23 (89). Airman, aged 33. *Day 1*: Headache and sore throat; off duty for one day. *Days 2–6*: Felt well. *Day 7*: After

usual work played rugby football. *Day 8 :* Severe pain in spine and chest with fever. Continued work. *Day 9 :* Severe paralysis of all muscles of the lower limbs and lower trunk

CASE 24 (91). Airman, aged 22 *Days 1 and 2 :* Sore throat and headache. Quiet days on board ship *Day 3 :* Ashore walking around all day. In evening developed sacral pain. *Day 7 :* Paralysis of abdominal muscles and thighs.

CASE 25 (84). Airman, aged 23. *Day 1 :* Cold in head and sore throat for two days *Days 3–9 :* Tired, but weather very hot *Day 10 .* Very hard badminton match. In evening developed fever and pain in head and neck. *Day 13 :* Severe paralysis of both upper limbs

CASE 26 (71). Schoolboy, aged 14. Had cold for three or four days. A week later he played rugby football, and on the night following developed pain in the back and a few days later slight abdominal paralysis.

In the series of 100 cases studied there are 4 further examples of this type among the group of "typical" cases with a minor illness. There are also 9 among the "typical" cases without a minor illness in which the pre-paralytic stage with spinal symptoms was immediately (within 2 to 24 hours) preceded by some special physical activity as in the following examples.

Special physical activity immediately preceding spinal symptoms of the major illness in "typical" paralytic cases with no reported minor illness symptoms

CASE 3 (28). Male, aged 12 Football six hours before onset.

CASE 19 (1) Female, aged 33 Six hours spent washing for a school, extra to usual work, eight hours before onset.

CASE 27 (4). Male, aged 13 Long run (several miles) soon after beginning of school term, sixteen hours before onset.

CASE 28 (86) Male, aged 22. Tennis tournament all day twenty-four hours before onset. Yachting six hours before onset.

CASE 29 (94). Male, aged 21. Tennis tournament twenty-four hours before onset

Case 30 (90). Male, aged 28 Playing squash-rackets three hours before onset.

Type of physical activity related to site of paralysis There have been many reported instances of the paralysis of poliomyelitis being worse in those muscles which were most exercised at the onset of the illness Table V gives several examples of this correlation between the type of physical activity and the site of maximum paralysis, and thus provides further evidence regarding the harmful effect of physical activity.

Effect of transporting patient in acute stage Clinicians have often suspected that a long journey to hospital may be harmful, while cases have been reported of the major illness following a long journey by road. Lenarsky *et al* (1951) confirm these fears, and find that patients who have had to be transported further to hospital are more likely to become severely paralysed than are those who live near the hospital.

TABLE V

Comparison between type of exercise and permanent paralysis

Case No	Day of exercise in relation to day of onset of pre-paralytic stage (D) and to day of paralysis (P)		Type of exercise	Site and severity of paralysis (slight +, moderate + +, severe + + +)
	D	P		
13 (44)	3	1	Half-mile race	Lower limbs + + +
4 (39)	− 1	− 3	Four-mile race	Trunk + + + Lower limbs + + +
(52)	1	− 1	Schoolboy playing organ for 1 hour R leg special strain	L arm + + R leg and thigh only + + +
(70)	1	1	Throwing chain with R arm, surveyor	R upper limb + + + L leg + +
(51)	3	− 1	Severe asthma	Abdomen + + + Intercostals + + + R shoulder + + R thigh + +
(83)	1	3	Playing piano for 1½ hours R hand special strain in the piece played	R arm and hand only + + +
17 (6)	1 2, 3	12, − 1	Milkman on feet all day	Trunk and thighs + + + Legs +

Local trauma In addition to the effects of physical effort described above, there have been many examples of poliomyelitis following local trauma (including operation) in which the paralysis developed an overwhelming preponderance in that part of the body which was involved by the injury.

Poliomyelitis developing 10 days after an operation on left forearm—flail left upper limb resulted

CASE 33. A boy, [illegible]
and ulna on 5 10.49
open reduction was car[illegible]
pain in the back of the head and nausea. He was transferred to the Western Hospital, Fulham (Dr. Kelleher), where he was found to have meningeal signs. Within a few days he developed complete paralysis of the left upper limb, which was permanent. The lower limbs and trunk were not affected but there was some weakness of the right arm The cerebrospinal fluid after the onset of paralysis was found to contain 30 mg. per 100 c.mm. and 30 cells per c.mm., mostly lymphocytes

Poliomyelitis developing during a course of electroconvulsion therapy followed by a rapidly fatal form of the disease

CASE 34. A man, aged 30, while having electroconvulsion therapy once daily for schizophrenia, developed headache and fever on 26 10 49 He was at once transferred to the Western Hospital, Fulham, where he quickly developed widespread paralysis. The cerebrospinal fluid contained 140 cells per c mm. and 190 mg. of protein per 100 c cm Breathing was maintained in a respirator from 7 30 p m. on 27 10.49, but he died at 3 p m. on 28 10.49. Post-mortem examination confirmed the diagnosis . severe changes were seen in the brain stem and motor cortex as well as in the spinal cord (Figs 1 and 2).

Harrington (1951) has also found that trauma shortly preceded the onset of paralytic poliomyelitis in 5 of 100 army cases. In each case the site of maximum paralysis was related anatomically to the site of the injury.

Tonsillectomy With regard to tonsillectomy, it seems undoubted that poliomyelitis developing soon after tonsillectomy has an increased liability to develop the dangerous bulbar type of palsy (case 35, p. 30), but what is even more disturbing is the recent statistical evidence that an undue proportion of those who develop bulbar poliomyelitis have previously, often long before, had their tonsils removed Lucchesi and La Boccetta reported this in 1955, and their findings have been corroborated by others *

Poliomyelitis following Inoculations. It has also become evident that poliomyelitis following within a month of a prophylactic inoculation is liable to lead to a preferential paralysis of the limb injected (McCloskey, 1950) † Hill and Knowelden (1950) con-

* See Editorial in *J Amer med Assoc*, April 3, 1954, p 1180
† See also papers in *Amer J Hyg*, February, 1952

firmed these findings, and further found statistical evidence which suggested that the inoculation not only led to maximum paralysis in the arm injected, but that inoculation actually contributed to the development of a major illness in what would otherwise have presumably been an abortive case.

Any suggestion that these localized post-inoculation cases might have been due to a form of shoulder-girdle neuritis can be definitely discounted, and follow-up study by Geffen *et al.* (1953) has shown clearly that the weakened muscles recover to the same extent as occurs in other cases of poliomyelitis

Bodian (1954) has been able to reproduce experimentally the provoking effect of intramuscular injections in monkeys who were infected with poliomyelitis virus by the intracardiac route He found that the harmful provoking effect of an intramuscular trauma by injection continued to operate for an interval of up to two weeks between the local trauma and the intracardiac injection He concluded that the effects of the local trauma seemed to be on the blood vessels of the spinal cord, and that this effect in some way interfered with the blood-brain cell barrier. Trueta and Hodes (1954) have also made some experimental observations on this matter

T A B. Inoculation on right arm Acute illness 7 days later, paralysis of right arm

CASE 31 (12) A newly conscripted soldier, aged 18 *Day 1* A T A B inoculation was given by subcutaneous injection on the outer [illegible]

fever (103° F — 39 4° C) were added to symptoms. *Day 9* The cerebrospinal fluid contained 133 white cells per c mm and 75 mg of protein per 100 ml *Day 10* Paralysis of right deltoid, biceps and triceps No other muscles were affected

Paralytic poliomyelitis following diphtheria-pertussis inoculation

CASE 40 (S M 636) Female, aged 12 months *Day 1* Diphtheria-pertussis inoculation into left thigh *Days 5-12* Catarrhal illness, fever, "wretched" *Day 18* Drowsy and irritable *Day 19* Onset of paralysis, admitted to hospital Respiration jerky and irregular, meningism Paralysed legs, trunk and left arm *Days 20-29* Treated in tank respirator *Day 60* Total paralysis of the left lower limb persists, partial paralysis of right lower limb, right trunk and right shoulder girdle

Severe paralysis of lower limbs and trunk 10 days after several intramuscular injections in buttocks

CASE 32 (101). Schoolgirl, aged 10 *Day 1 :* Severe earache, for which she was given intramuscular injections of penicillin into the buttocks every four hours for three days. *Day 8 :* Felt tired and had a slight headache on waking. Though her temperature was normal at lunch-time it was raised a little by the evening. Slight activity during the forenoon ; then went to bed. *Day 9 :* Slight sore throat added to symptoms In bed all day. *Day 10 :* Felt quite well In bed all day, except that she got up to motor home—one hour's journey. *Day 11 :* Developed moderately severe pains in both thighs In bed all day. *Day 12 :* Severe paralysis of both lower limbs and lower trunk muscles. This was still very severe two months later. (Her brother also had pains in the thighs at about the same time but did not develop paralysis)

DISCUSSION OF PROVOKING FACTORS AND PREVENTION

Some of the above evidence does not carry complete conviction, but we must accept much of it and attempt to adjust our attitude to the disease accordingly. For example, it seems preferable to hold athletic contests out of the poliomyelitis season, which is chiefly from August to November School " Sports " at the end of July should therefore be discouraged ; the month of May is much safer than July in the Northern Hemisphere from this point of view

With regard to the general supervision of children, a rest-period during the day is beneficial from every point of view, and it is worth while, during epidemics, to take extra trouble to supervise and prolong periods of physical rest, and at the same time to limit the amount of that severe type of physical exercise which is often practised to great excess during holiday months.

The first few weeks after reassembly of school in the autumn should be a period of watchfulness, as there may be carriers among the pupils and staff.

Public health measures designed to isolate possible cases of poliomyelitis may lead to patients being submitted to exhausting journeys to hospital at a stage of the disease for which complete rest is most urgently needed The physician should protect his patients from such measures, for the value of these has never been proved as far as poliomyelitis is concerned

In most instances the patient's interests alone should be taken

into account when deciding whether or not he should be sent to hospital, but this decision often presents difficulties which are discussed in Chapter VI

With regard to operations and injections, it is generally agreed that operations on the nose and throat should, if possible, be avoided during the epidemic season owing to the danger of a subsequently occurring poliomyelitis assuming the bulbar form. Prophylactic inoculations should also be given, where possible, outside the epidemic period

The dangers of syringe infection must always be remembered ; heat sterilization for needles and syringes is required before inoculations of all kinds

Severe paralysis of lower limbs and trunk 10 days after several intramuscular injections in buttocks

Case 32 (101). Schoolgirl, aged 10 *Day 1 :* Severe earache, for which she was given intramuscular injections of penicillin into the buttocks every four hours for three days *Day 8 :* Felt tired and had a slight headache on waking. Though her temperature was normal at lunch-time it was raised a little by the evening. Slight activity during the forenoon ; then went to bed. *Day 9 ·* Slight sore throat added to symptoms. In bed all day. *Day 10 :* Felt quite well In

trunk muscles. This was still very severe two months later. (Her brother also had pains in the thighs at about the same time but did not develop paralysis)

Discussion of Provoking Factors and Prevention

Some of the above evidence does not carry complete conviction, but we must accept much of it and attempt to adjust our attitude to the disease accordingly For example, it seems preferable to hold athletic contests out of the poliomyelitis season, which is chiefly from August to November. School "Sports" at the end of July should therefore be discouraged ; the month of May is much safer than July in the Northern Hemisphere from this point of view.

With regard to the general supervision of children, a rest-period during the day is beneficial from every point of view, and it is worth while, during epidemics, to take extra trouble to supervise and prolong periods of physical rest, and at the same time to limit the amount of that severe type of physical exercise which is often practised to great excess during holiday months

The first few weeks after reassembly of school in the autumn should be a period of watchfulness, as there may be carriers among the pupils and staff.

Public health measures designed to isolate possible cases of poliom

journey

rest is

patients from such measures, for the value of these has not been proved as far as poliomyelitis is concerned

In most instances the patient's interests alone should be taken

into account when deciding whether or not he should be sent to hospital, but this decision often presents difficulties which are discussed in Chapter VI.

With regard to operations and injections, it is generally agreed that operations on the nose and throat should, if possible, be avoided during the epidemic season owing to the danger of a subsequently occurring poliomyelitis assuming the bulbar form Prophylactic inoculations should also be given, where possible, outside the epidemic period.

The dangers of syringe infection must always be remembered; heat sterilization for needles and syringes is required before inoculations of all kinds

CHAPTER VI

MANAGEMENT AND TREATMENT

Minor illness. It is only during a severe epidemic of poliomyelitis that the minor illness is likely to attract any attention. During such an epidemic, however, it is wise to remember that a short-lived minor catarrhal upset (often lasting only one day) may be due to infection with the virus Extreme restrictions with regard to physical activity are not then justifiable, but it does seem reasonable under these circumstances to see that for the next ten days or so the patient should be protected from undue fatigue

Major illness The onset of the major illness leads to many difficult problems in management. The first point to stress is that the studies referred to in a previous section (p 47) indicate that physical activity of any kind at this stage is dangerous, and every effort must be made to ensure physiological rest at the earliest possible moment. The illness has now reached the critical stage, and within a few hours or days the fate of tens of thousands of motor cells will be decided. It is evident, therefore, that complete rest in bed must be enforced *at once*, regardless of the inconvenience and difficulties this may cause. Here at once we encounter the serious problem regarding the desirability of transferring suspected cases to hospital. During epidemics many cases reach hospital before paralysis has developed. These cases are therefore being submitted to a frightening and may be exhausting experience at the very time that complete rest is most desirable.

This situation is disturbing for it often leads to the question —"Would the paralysis have developed so severely, or indeed at all, if the patient had been kept quietly at home during the critical phase of the major illness ?" On the other hand, the development at home of bulbar palsy or respiratory paralysis is a possibility to be dreaded, unless a mobile unit is available to go to the patient when this develops.

A child who is confused, unconscious or very drowsy should always be sent to hospital, as the diagnosis may prove to be some type of meningitis requiring immediate treatment; and hospital

treatment is generally required for such seriously ill patients In other cases it will be appreciated that home circumstances necessitate individual assessment; but it seems that the indiscriminate transfer of *all* suspected cases to hospital is not desirable even during an epidemic, for it then seriously increases the burden on hospitals which are probably already unable to deal properly with the dangerously ill Under epidemic conditions also small mobile units are very valuable, as such units can be transferred to assist with local outbreaks of the disease, to carry out special investigations (such as lumbar puncture) on patients in their homes, can observe the progress of doubtful cases, and be equipped to maintain artificial respiration during transportation to hospital should this prove to be necessary (Russell, 1952; Lassen, 1953).

The decision to move the patient to hospital or not, should therefore generally be taken from the point of view of the patient's interests alone The other members of the family have probably already been exposed to the virus, and the increased risk involved by keeping the patient at home is very slight, and should certainly take second place when it is considered dangerous to move the patient It is generally agreed that attempts to control the spread of infection in poliomyelitis have not yet been shown to contribute appreciably towards the purpose intended

The localized and unexpected outbreaks of poliomyelitis cause great alarm to the local community, and most Medical Officers of Health feel obliged to advise transfer of all cases to isolation hospitals This has often led to a quickly developing state of chaos in the receiving hospital which involves great hazard to the patients admitted so precipitously many otherwise avoidable deaths have resulted from this commonly applied policy.

More rational by far is the recent American tendency to treat straightforward cases of poliomyelitis at home during the major illness (Stimpson, 1952), but this is still an anxious matter, and the doctor is well advised to share the responsibility for such a decision with a colleague or specialist

Isolation

Isolation precautions are generally practised, though their effectiveness in this disease has never been fully established

The typhoid type of precautions are appropriate, and some authorities advise isolation of contacts for a period of two to three weeks, especially in the early cases of an outbreak, when there is sometimes evidence of a narrow stream of infection (Francis, 1952, Bradley, 1950) such as on theoretical grounds should be to some extent controllable by public health measures. However, in other outbreaks the virus seems to be very widespread and only becomes apparent by affecting scattered individuals who presumably have less immunity or are exposed to an excessive quantity of the virus

One possible reason for the general ineffectiveness of Public Health measures is that the patient is infectious before he has symptoms thus, as has already been pointed out, the virus has already invaded the blood stream at the time of the minor illness, and when the major illness begins there is already a high specific antibody response to the virus concerned (see Melnick *et al*, 1954) The important studies by Melnick and Ledinko (1953) on the numerical ratio of clinical cases to inapparent infections has already been considered (p 12)

Provision of Adequate Hospital Treatment

The great majority of cases of suspected poliomyelitis are however still sent to hospital, and every effort should be made to ensure that they get all the treatment required Thus, the Poliomyelitis Committee of the Royal College of Physicians in its second interim report (1953) wrote.

Disposal of acute cases of poliomyelitis

Each Regional Board should make provision in advance for the adequate care of sporadic cases, and should prepare a plan for dealing with a possible epidemic

The Committee are of the opinion that patients with acute poliomyelitis should, except in an emergency, only be admitted to hospitals, whether infectious disease(s) hospitals or others, in which the requirements set out in this memorandum can be fulfilled.

Medical and nursing care in hospital

Patients in the acute stage of poliomyelitis may suddenly develop complications which will make exacting demands on the nurses and doctors. Shortage of experienced staff, lack of good hospital facilities, or difficulty in getting immediate assistance from certain specialists may quickly lead to disaster.

Medical staff

The general medical care of poliomyelitis in the acute stage requires:

(*a*) Immediate supervision by registrars or senior registrars who have had at least a short course in the care of acute poliomyelitis

(*b*) House officers who can be trained by the consultants or experienced registrars, so that one competent doctor can be summoned to a case at very short notice

(*c*) Anæsthetists or E.N.T. specialists who are available day or night to assist in maintaining a free airway—often a vital requirement.

(*d*) A team of consultants, comprising neurologists, general and infectious diseases physicians, pædiatricians, orthopædic surgeons and thoracic surgeons who have a knowledge of acute poliomyelitis

Care must be taken, however, to avoid the danger of too many specialists confusing management of the case

The number of medical staff required during epidemics varies from day to day according to circumstances, but in a sharp local outbreak all the medical, pædiatric, orthopædic and E N T registrars in the area could, with advantage, be available to help, and should therefore have had some special instruction in the care of acute poliomyelitis.

Nurses

The complex methods of treatment which may be required make it necessary to have nurses with special experience, but in epidemics the number of experienced nurses will often be inadequate. In addition to the nurses who have already been trained in the care of patients with poliomyelitis in infectious disease hospitals, a panel of nurses who volunteer to treat cases in the acute stage should be prepared in all regions They should be given practical instruction as soon as possible and should immediately be released from other work if their services are required in an epidemic In compiling the list of volunteers, preference should be given to nurses who have had experience in the general medical, pædiatric or orthopædic wards of a general hospital.

Similar recommendations are made in a Ministry of Health circular (1953)

It is of course quite impossible to provide all these conditions in some of the hospitals which receive acute cases This applies specially to the smaller infectious disease hospitals, so there is much to be said for treating poliomyelitis in medical wards allotted for this purpose in general hospitals, and where this has for long been practised there is no convincing evidence that it leads to an increased risk of cross-infection

The typhoid type of precautions are appropriate, and some authorities advise isolation of contacts for a period of two to three weeks, especially in the early cases of an outbreak, when there is sometimes evidence of a narrow stream of infection (Francis, 1952; Bradley, 1950) such as on theoretical grounds should be to some extent controllable by public health measures. However, in other outbreaks the virus seems to be very widespread and only becomes apparent by affecting scattered individuals who presumably have less immunity or are exposed to an excessive quantity of the virus.

One possible reason for the general ineffectiveness of Public Health measures is that the patient is infectious before he has symptoms: thus, as has already been pointed out, the virus has already invaded the blood stream at the time of the minor illness, and when the major illness begins there is already a high specific antibody response to the virus concerned (see Melnick *et al*, 1954). The important studies by Melnick and Ledinko (1953) on the numerical ratio of clinical cases to inapparent infections has already been considered (p 12).

Provision of Adequate Hospital Treatment

The great majority of cases of suspected poliomyelitis are however still sent to hospital, and every effort should be made to ensure that they get all the treatment required. Thus, the Poliomyelitis Committee of the Royal College of Physicians in its second interim report (1953) wrote:

Disposal of acute cases of poliomyelitis

Each Regional Board should make provision in advance for the adequate care of sporadic cases, and should prepare a plan for dealing with a possible epidemic.

The Committee are of the opinion that patients with acute poliomyelitis should, except in an emergency, only be admitted to hospitals, whether infectious disease(s) hospitals or others, in which the requirements set out in this memorandum can be fulfilled.

Medical and nursing care in hospital

Patients in the acute stage of poliomyelitis may suddenly develop complications which will make exacting demands on the nurses and doctors. Shortage of experienced staff, lack of good hospital facilities, or difficulty in getting immediate assistance from certain specialists may quickly lead to disaster.

Medical staff

The general medical care of poliomyelitis in the acute stage requires:

(*a*) Immediate supervision by registrars or senior registrars who have had at least a short course in the care of acute poliomyelitis.

(*b*) House officers who can be trained by the consultants or experienced registrars, so that one competent doctor can be summoned to a case at very short notice

(*c*) Anæsthetists or E.N.T. specialists who are available day or night to assist in maintaining a free airway—often a vital requirement.

(*d*) A team of consultants, comprising neurologists, general and infectious diseases physicians, pædiatricians, orthopædic surgeons and thoracic surgeons who have a knowledge of acute poliomyelitis

Care must be taken, however, to avoid the danger of too many [illegible]

had some special instruction in the care of acute poliomyelitis

Nurses

The complex methods of treatment which may be required make it necessary to have nurses with special experience, but in epidemics the number of experienced nurses will often be inadequate In addition to the nurses who have already been trained in the care of patients with poliomyelitis in infectious disease hospitals, a panel of nurses who volunteer to treat cases in the acute stage should be prepared in all regions They should be given practical instruction as soon as possible and should immediately be released from other work if their services are required in an epidemic In compiling the list of volunteers, preference should be given to nurses who have had experience in the general medical, pædiatric or orthopædic wards of a general hospital.

Similar recommendations are made in a Ministry of Health circular (1953).

It is of course quite impossible to provide all these conditions in some of the hospitals which receive acute cases This applies specially to the smaller infectious disease hospitals, so there is much to be said for treating poliomyelitis in medical wards allotted for this purpose in general hospitals, and where this has for long been practised there is no convincing evidence that it leads to an increased risk of cross-infection

However, in considering this matter it should be appreciated that over 80 per cent of acute cases of poliomyelitis survive the acute illness however they are treated. Their lives are never in danger and they can, without serious risk, be looked after by untrained nursing staff. Some of the muscles may get tight, but this can be corrected later by simple forms of physiotherapy. Unfortunately, however, a very expert degree of supervision is required to recognize early the cases requiring special measures, for the core of the problem of hospital care depends on the need to provide extremely expert supervision for about 20 per cent of all paralytic cases. This is required in order to prevent any form of respiratory insufficiency which is the cause of death in nearly all fatalities

Special Respiration Units

In order to provide efficiently and rapidly for the dangerous forms of the disease the writer has for some years been advocating the establishment of Special Respiration Units which will take

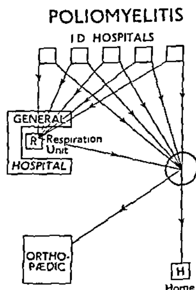


Fig 9 —To show how one respiration unit attached to a large general hospital can serve several infectious disease (I D) hospitals

charge of difficult cases, transferring them if necessary to the hospital of choice. Some such plan is essential if the mortality rate is to be kept at the lowest possible. For example, in Oxford, with full support from the Medical Officer of Health, we have set up a Unit at the Radcliffe Infirmary. The Unit is in the charge of a physician; it is isolated within the hospital and specially trained nursing staff are seconded from other wards when required. The most important contribution comes from anæsthetists, who nowadays have special experience in keeping the airways clear under conditions which include curare paralysis, coma from an anæsthetic, and an open chest with pus in the bronchi The anæsthetists should be prepared to take charge of some cases and supervise them as they would an anæsthetic, which however may last for some weeks instead of a few hours This kind of supervision can only be proved by a large anæsthetic service, and for this reason these special units can only operate efficiently in or beside a big general hospital (Fig. 9) Only the difficult cases with respiratory problems are admitted to the special Unit, and a mobile squad is available day and night to transfer a case safely—the usual safeguards being laryngeal intubation (if necessary), removal of secretions, postural drainage and positive pressure breathing during the journey if required

Effects of an Epidemic on Hospital Care

It has already been pointed out that during an epidemic of poliomyelitis a considerable proportion of cases sent to the receiving hospital will have been wrongly diagnosed

Though many cases of paralytic poliomyelitis are never dangerously ill, others arrive at hospital *in extremis* from the effects of respiratory paralysis or of respiratory collapse due to secretions being inhaled *via* a paralysed pharynx and larynx, and the patient who arrives in good condition may, of course, quickly develop these critical complications

The only safe way to deal efficiently with all these disturbing possibilities is for an experienced physician to see the case "on the door-step" of the hospital, or to visit the patient in his home first

As there is no known means of determining the patient's prospects during the pre-paralytic phase, it is necessary to watch

all cases carefully until the spread of paralysis ceases. Only by so doing can the development of dangerous complications be recognized in time to prevent disasters such as the inhalation of vomit or massive lung collapse.

The prevention of dangerous complications should be the first aim of every unit admitting cases, while other aspects of treatment such as care of the limb muscles in the acute stage are of subsidiary importance. These views require emphasis, for some small hospitals still consider that their chief function is to isolate patients and "to hope for the best", without making any serious attempt to provide for dangerous complications Others, again, are so concerned with the paralysed limbs that their treatment overlooks the measures required to prevent pulmonary atelectasis.

One of the greatest difficulties is to ensure that cases of spreading paralysis are watched by doctors and nurses who are familiar with the problems which may arise. Such close personal supervision is required throughout the 24 hours that it is often desirable that an experienced doctor should be within 2 minutes' call both day and night. Sharp outbreaks of poliomyelitis often appear in areas which have had little recent experience of the disease, while a local outbreak is often followed for several years by a low incidence in that area Hence, those who have acquired good experience of the disease are often not in the right place to be able to help with the next outbreak. The difficulties therefore are formidable, but the clear recognition of the problems should facilitate a solution appropriate to varying local conditions

Management of the Case

Complete physiological rest for the nervous system is by far the most powerful line of treatment yet at our disposal in the acute stage, and for the critical early days it seems worth while to take endless trouble to achieve this Children must, of course, be kept in bed, but in addition they must be kept physically and emotionally relaxed The parents should realize that for a few critical days great sacrifices are worth while to ensure full relaxation of a young child by reading or rocking to sleep The situation is so critical in the early days that the father, for example, should be prepared to stay off work for a few days to assist in

coaxing the young patient to relax and sleep as much as possible. Pain must be relieved by analgesics (such as Tab. Codein Co.), and barbiturates may be used to induce slight drowsiness, provided there are no bulbar symptoms. It is, of course, obvious that physiological rest includes avoidance of talking, sucking and chewing. Indeed it is desirable that the patient should do nothing for himself, not even feed himself or hold a book. Visitors are generally better avoided, as they stimulate a patient who should be drowsy and inactive. The sick-room must reflect an atmosphere of efficiency and confidence.

In older children and adults the attitude should be, "You'll be quite all right, but you must relax, lie quietly and sleep as much as possible." Adults should be told dogmatically that the best thing they can do to help is to lie quite still and sleep.

Lumbar puncture. If typical paralysis has already appeared and the diagnosis is therefore certain, there is nothing to be gained by lumbar puncture—indeed some have suggested (without much evidence) that lumbar puncture might do harm.

This test must, however, always be done without delay when the nature of a serious intracranial infection is in any way uncertain, for it is only by this test that early diagnosis of the various forms of bacterial meningitis can be made. With the improved modern methods of treatment available for several acute intracranial diseases, it is most important to establish an accurate diagnosis rapidly; at least one must ensure that a condition requiring urgent specific treatment is not being overlooked.

PRINCIPLES OF NURSING CARE

There are very few diseases in which the nurse plays a more important and more responsible part in treatment than in acute poliomyelitis.

In the first place many of the patients arrive fully conscious and very frightened. She should therefore inspire that confidence which allays fear and allows the patient to relax, both physically and mentally. Both physical and mental rest are extremely important in the pre-paralytic phase, and sedation with

barbiturates is often advised provided that bulbar symptoms are not prominent (Brehme and Leuterer, 1953).

Poliomyelitis bed. The patient's bed should be specially planned. A fracture bed board is required to keep the mattress quite firm. A soft rubber mattress (Dunlopillo) is best, but without any thick rubber covering (which removes many of the merits of this mattress). If a waterproof covering is necessary a thin sheet of plastic material is acceptable. The mattress should be 4 inches shorter than the bed so that when lying prone the patient's toes hang over the end of the mattress. A foot board should be held beyond the mattress by two 4-inch wooden blocks Pillows are better avoided entirely. Blankets should be few and light to avoid all sense of construction on the body or limbs The ward should be kept at a temperature of not less than 65° F.

A good supply of small pillows and pads should be available to provide local support to joints which are uncomfortable For example, a soft pad under the neck, under the small of the back or under the knees allows the patient to relax in greater comfort.

Posture and passive movements. A large part of the nurse's effort is at first directed towards making the patient as comfortable as possible and she should never tire of making small changes in position which will often give temporary relief

A complete change of posture is desirable every 2 to 4 hours, especially when there is any weakness of the muscles of respiration. The lateral, semi-prone and prone postures are specially suitable (Figs 10, 11 and 12). Lying on the back (supine) should seldom be allowed if there is weakness of the muscles of swallowing or of respiration owing to the danger of inhaling secretions or vomit in this position.

Most patients are very sensitive to movement of any kind, but if left for long in one position this hyperæsthesia is likely to become worse. Hence the nurse should take every opportunity to move the patient's limbs short of causing much pain, indeed she should be carefully instructed in gentle passive movements to all the main joints and muscle groups so that these movements can be repeated both day and night when the physiotherapists are rarely available. Frequent passive movements and changes of posture ultimately increase the patient's comfort, and prevent

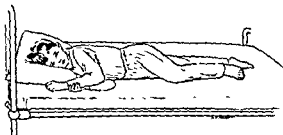


Fig 10

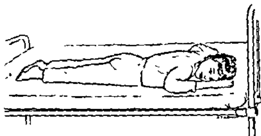


Fig 11

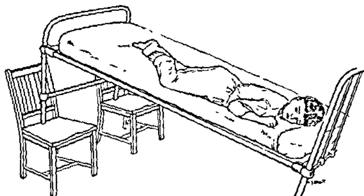


Fig 12

Figs 10, 11 and 12 —Lateral, prone and semi-prone postures respectively In Fig 12 the foot of the bed is raised 18 inches to encourage postural drainage

the development of tight muscles ("muscle spasm"). Changes of posture from one side to the other are specially important in cases of respiratory weakness, as they reduce the danger of pulmonary complications. Rigid splinting of all kinds should be avoided, as prolonged immobility of a paralysed muscle is always harmful.

The *methods of examination required for the diagnosis of* paralytic poliomyelitis have already been considered and it is necessary as part of the management of the acute disease for the nurse to report on any paralysis she may notice, especially during the early days of the disease. Her interest in this, however, should on no account be fatiguing to the patient.

It is essential also that a close watch be kept on the state of the respiratory muscles and a half-hourly record of pulse and respiration is often necessary. An experienced nurse will be able to report accurately on the development of complications such as dysphagia, feeble respiration, atelectasis or retention of urine.

Nursing reports. The nurse should therefore observe, record and report the following points:

1. Temperature.
2. Blood pressure.
3. Pulse, including rate, rhythm and volume.
4. Rate, depth and character of respiration; waking and sleeping chart at least 4-hourly, any use of accessory muscles of respiration (alæ nasi, sternomastoids).
5. Colour.
6. Mental alertness and responsiveness.
7. Refusal of food, dysphagia, nasal regurgitation, vomiting Mucus in the throat or ineffective cough.
8. Speech disturbances, in particular nasal voice and loss of voice power.
9. Bladder and bowel function, with intake and output chart as *required*
10. Weakness or paralysis of any part
11. The positions spontaneously adopted by the patient and the sites of pain, spasm and tenderness.

It should be understood that when complications develop, any failure to recognize quickly that things are going wrong is likely to have very serious consequences.

The Development of Paralysis

The older child or adult patient may become very frightened when paralysis appears and parents may become very anxious. This psychological reaction sometimes seems to mislead the doctor in charge, and indeed failure to recognize the paralysis of poliomyelitis is by no means uncommon, often due probably to the fact that such patients often appear to be too well to have any serious disease.

Case in which the diagnosis of paralytic poliomyelitis was "missed"

CASE 41 (R I N. 6661) Female, aged 19, a student of ballet *Days 1–4* · "Flu", fever and headache. *Day 5* . Lower lumbar pain aggravated by jarring her body *Day 6* . Better and able to be out-of-doors. *Day 7* (evening) Lumbar pain returned—severe and prevented her sleeping; she would get up frequently and walk about [illegible]

[illegible]

The practical needs of the clinical situation have already been referred to, and the need to influence the patient's psychological reaction has been stressed The administration of sedatives often seems to be desirable, and the patient, if conscious, must be warned that he must lie quite still, as it is not uncommon for the older child or adult to make the disastrous mistake of thinking that they must keep their limbs moving to counteract the spread of the paresis Once paralysis begins to make its appearance, the patient should not be left unattended until the maximum paralysis has developed This spread of paralysis usually continues for less than three days.

CHAPTER VII

TREATMENT OF BULBAR POLIOMYELITIS

THE symptoms and signs of bulbar poliomyelitis have already been briefly described, and the vital importance of distinguishing the various forms of respiratory insufficiency from each other has been emphasized. The term bulbar involvement has in the past often been wrongly used to account for the development of coma and death, when in fact the fatal outcome was due to the complications of respiratory insufficiency and not directly to virus lesions in the brain stem. It has become recognized that death in poliomyelitis is usually due to the direct or indirect consequences of respiratory insufficiency, and that the inflammatory reaction in the brain stem is only very rarely of sufficient severity to cause death in itself. For this reason it is important that the critical physician should not accept as a cause of death virus involvement of the brain-stem, except in rare circumstances.

The proper treatment consists of preventing anything which may lead to respiratory insufficiency, and depends largely on skilled nursing attention, and on the prompt recognition of complications should they occur. The patient with bulbar poliomyelitis may be comatose, confused or fully alert In most cases the strength of respiration is adequate provided the lungs remain healthy, so that the main need is to protect the lungs from the dangers of aspiration, atelectasis or pneumonia. Coma in itself carries certain dangers of aspiration as far as the lungs are concerned, but the special danger in bulbar cases is dependent of the common occurrence of paralysis of the pharynx and larynx This throat paralysis is potentially most dangerous, especially in association with coma, and yet if promptly recognized and properly treated at least 80 per cent of such cases will not only survive, but will make an almost complete recovery without permanent paralysis of any kind

Thus "the dreaded bulbar cases" if properly treated carry a more favourable prognosis than do the severe spinal forms of poliomyelitis

Postural Drainage

The need for postural drainage of the air passages is often recognized by just listening to the patient's breathing, for there is an audible " death rattle " caused by air bubbling past a pool of secretions in the throat. This demands immediate action by the general practitioner who first sees the case, and the patient will usually be found lying in bed in a half-sitting posture. All pillows must at once be removed, whether the patient objects or not, and the patient turned on his face into the prone or semi-prone position For a time, at least, the foot of the bed should be raised 18 inches (Fig 12) in order to give an angle with the horizontal of about 15 degrees

This simple procedure leads to a large volume of secretions flowing out of the mouth from the pharynx and trachea, and a good supply of towels and swabs is needed The immediate relief to the patient's breathing and his critical condition is most dramatic, for the proper use of postural drainage provides one of the most remarkable (and simple) life-saving procedures in clinical medicine This of course applies also to the handling of some other diseases

Careful posturing should therefore be instituted in the home or ambulance as soon as the dangers of inhalation are recognized. Often these patients are children who, if left unattended, will sit up and inhale vomit The effects of inhaling gastric contents

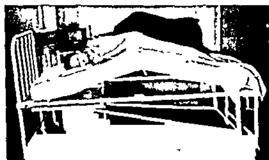


Fig 13 —Adjustable inverted " V " bed generally suitable for the prone or semi-prone posture, but here used for a posture which is almost lateral The child is wearing a throat microphone which leads to a loudspeaker

often cause a fatal collapse and death some hours later, and no form of known treatment (including bronchoscopy) will prevent this result after such inhalation has occurred. At post-mortem examination the large areas of lung necrosis caused by the digestive juices are obviously incompatible with survival.

Nursing on the back is always dangerous in bulbar cases unless the bed is tilted very steeply. On the other hand the prone or semi-prone posture is often safe without raising the foot of the bed. However, the foot of the bed should be raised from time to time as required, and inverted "V" beds are specially useful and quickly adjustable for this purpose (Fig. 13). The lateral posture may also be used, and the tilted posture may be relaxed for nursing or other reasons, provided it can be re-established within a second or two should the child, for example, vomit unexpectedly or choke while attempting to swallow. A simple harness around the child's shoulders and secured to the foot of the bed prevents him sliding out of position when the bed is steeply tilted.

Medical and Nursing Supervision

During the period of pharyngeal paralysis the patient's every breath should be listened to, preferably with the assistance of a throat microphone, so that any accumulation of secretions in the upper air passages may be promptly recognized (Stott, 1953), and so that irregularity or failure of respiration or retching may also be observed quickly. The nurse can herself deal with minor accumulations of secretions by increasing the tilt of postural drainage and using the sucker However, she should also have immediate access to a doctor versed in the methods of aspirating the trachea, and there should be quick access also to one who can perform the operations of bronchoscopy, laryngeal intubation or tracheotomy

As has already been mentioned, many bulbar cases retain adequate strength in the respiratory muscles, but careful watch must be kept not only for weakening of the respiratory muscles but also for failure of the respiratory centre to maintain the regular respiratory rhythm In cases with respiratory weakness the development of atelectasis may immediately precipitate a crisis, as the muscles may at once become inadequate for the

reduced available lung tissue. Any of these developments may require the use of artificial respiration, but the point at which this becomes necessary may be difficult to recognize The difficulty is greatest when the patient's consciousness is clouded, as there are then inevitable doubts as to whether the mental dulling is due to cerebral hypoxia or to the focal effect of the virus on brain-stem centres Anxiety in these cases is increased by the knowledge that the use of a respirator in the presence of pharyngeal paralysis is most hazardous owing to the danger of the machine sucking secretions into the lungs

There are several methods available which help. The blood pressure taken every 15 or 30 minutes may be most helpful, as a rise of blood pressure is often an early sign of CO_2 retention

The regular use of an oximeter may be useful in this type of case, as it will demonstrate moderate degrees of hypoxia for which mere inspection of the patient's colour is an unreliable indicator. A CO_2 meter should also prove to be useful

The use of assisted respiration with positive pressure to a well-fitting mask is often of value in these cases The Oxford inflating bellows may be used for this purpose and the assistance provided may be made to synchronize with the patient's own efforts When these measures lead to an improvement in the patient's condition or oximeter reading, then it may be generally assumed that some form of assisted respiration is required.

In the handling of difficult cases daily skiagrams of the lungs are required, as the presence of areas of inactive lung tissue greatly alters the rate of artificial respiration required, and also the volume of air or oxygen which can actually enter the lungs A study of the blood chemistry as referred to later is also necessary

Respiratory Failure combined with Pharyngeal Paralysis

The combined failure of respiration and also of the bulbar muscles may develop together, but usually either the respiratory or the bulbar paralysis precedes the other Whatever the order of their appearance, the grave problems presented by the combined lesion are the same, and it is with this type of case that there has recently been so much discussion and so much effort to improve the existing methods

Such patients may sometimes be handled successfully in the modern respirators when it is possible to nurse patients in the prone or semi-prone posture, and to tilt the respirator as required to assist the drainage of secretions from the upper air passages, but many difficulties may arise, and even a slight accumulation of secretions in the airways may quickly lead to a hopeless situation.

Tracheotomy may be done in a tank respirator, but exceptional nursing difficulties arise in the care of a tracheotomy tube in a respirator for it then becomes almost impossible to continue the frequent changes of posture which are desirable from the point of view of the lungs. However, many American clinics practise tracheotomy in respirator cases with paralysis of swallowing or obstructed airways, and depend on suckers and tilting of the respirator to obtain proper drainage. The use of a positive pressure phase in the respirator is helpful in this type of case

The Copenhagen Method (I.P.P.R.)

Professor Lassen (1953) and Dr. Ebsen evolved in Copenhagen, during the grave outbreak of 1952, a method of controlled respiration for cases developing respiratory insufficiency which is similar to that used by anæsthetists to maintain breathing when the muscles are curarized. After preliminary intubation of the larynx a high tracheotomy was performed, and a wide cuffed tracheotomy tube inserted to prevent the aspiration of pharyngeal contents. Positive pressure breathing was then maintained through the tracheotomy tube for as long as respiration remained inadequate. Intermittent positive pressure respiration (I P.P.R) was provided as in anæsthesia by briskly squeezing an anæsthetic bag to synchronize with the patient's own inadequate effort, and medical students were trained to do this in eight-hour shifts.

Professor Lassen used this method freely for all cases of respiratory difficulty so that he was able to dispense with the use of tank respirators almost entirely. He used a CO_2 absorption method in a semi-closed circuit, but the present tendency is to prefer open circuits which remove the need for CO_2 absorption

The tracheal and bronchial secretions required to be aspirated frequently with a strong sucker, and atelectasis, which was not infrequent, demanded bronchoscopy and vigorous physiothera-

peutic methods applied to the chest over the collapsed lung Frequent changes of trunk posture assisted drainage, but the cuffed tracheotomy tube, while preventing the passage of secretions downwards, also rendered it essential that all secretions spreading upwards from the bronchi should be removed by frequent suction. This must be done quickly in order to reduce the period of interfering with respiration. The same difficulty arises when bronchoscopy is required, as artificial respiration must not be interrupted for more than a short time in severe cases The need for suction is specially apparent after changes of posture and after vigorous pressure-vibration (Fig 19) to the chest by physiotherapists. The collection of secretions in the trachea and bronchi can be recognized by listening with a stethoscope over the tracheotomy tube cork.

A fine plastic œsophageal catheter is passed via the nose into the stomach in order to relieve gastric distension and to provide adequate nourishment (see also p. 85)

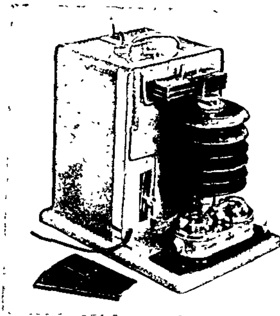
Mechanical pumps for intermittent positive pressure respiration

During the Copenhagen epidemic Lassen trained over 1000 medical students in the technique of bag ventilation. Various methods have been designed to provide a " mechanical student ". Pressure-controlled electrical devices have been used, the cycling of which depends on the height of intrapulmonary pressure (Bang, 1953, Macrae *et al.*, 1953, Pask, 1953) In these, however, the intrapulmonary pressure of air is always positive, and the absence of a phase of negative or zero intrathoracic pressure is thought to interfere with the return of blood to the heart.

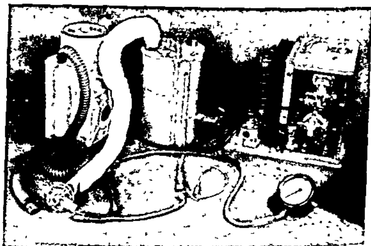
An alternative, and preferable, method is to pump air or oxygen (or both) into the lungs by a pump for which there is full control of maximum pressure, rate and volume. Thus a volume of 500 ml (actually reaching the lung) at 16 per minute, and a maximum pressure of 15–20 cm of water is adequate for an average adult with healthy lungs.

Fig 14 illustrates one such pump, *the Radcliffe Respiration Pump*, designed by Russell and Schuster (1953) and improved by H G East & Co* This apparatus will withstand many months of continuous operation, and can now be fitted with an alternative motor to run on 12 volts as well as the usual 230 volts

* 37A Oxford Road, Cowley, Oxford.



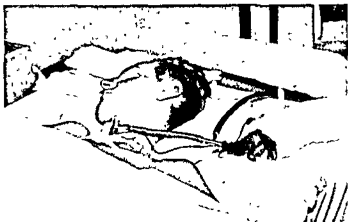
(a)



(b)

FIG 14 (*a*) and (*b*) —Radcliffe Respiration Pump (H. G. East & Co) and accessories

The pump has alternative motors, 12-volt D C, and 230-volt A C, humidifier, expiration valve, gas meter, cuffed tracheotomy tube, and pressure-gauge



(*c*)



(*d*)

FIG [illegible]

A.C. This makes the machine most suitable for transporting patients by air or road over long distances. Such patients have been brought from Africa to England using this machine (Harries and Lawes, 1955). A feature of these machines is that the pressure of delivery is determined simply by the gravitational effect of a weight which is adjusted according to the maximum pressure desired. The volume and speed are also controlled through a wide range.

Machines of this type require an expiratory valve which allows free expiration for a period slightly longer than the

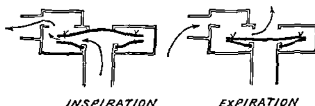


FIG 15 —Diagrammatic representation of mechanism of the Stott *expiratory valve.*

The case is made partly of metal and partly of plastic while the valve is of rubber

inspiratory phase. There are several possible types of expiratory valves available; that designed by Stott * is simple and satisfactory with very low resistance, but it needs to be changed every 3 or 4 hours for cleaning (Fig. 15).

The air o [illegible] saturated with moistur [illegible] (b)), as has been [illegible]

In our experience of several cases treated by this method (Crampton-Smith *et al*, 1954; Spalding and Young, 1955), these machines are adequate for nearly all cases. On theoretical grounds these pumps would be more effective if a negative pressure phase [illegible] supposed [illegible] rke and [illegible] *Radcliffe* pump has also been developed in this way.

Air alone is often suitable for use in such machines, but oxygen added or alone can be given as required by the patient's blood chemistry

* *Messrs Owen Mumford, Oxford*

Use of oxygen with I P.P.R.

In most cases the use of air alone for I P.P.R. is best, and indeed the use of oxygen may lead to difficulties, for it may prevent hypoxia while allowing a dangerous accumulation of CO_2. When oxygen is, however, used with I.P.P.R it must be led into the respiration pump in such a way as not to interfere with the action of the expiration valve. This valve only operates satisfactorily if during expiration a slight negative pressure develops in the system The best method of dealing with this is to lead oxygen or an oxygen-air mixture into an anæsthetic bag attached to the main inlet, and not to use the extra oxygen tap often provided in this type of apparatus. Similarly, in the Radcliffe pump, the valve at the delivery side of the bellows must be put out of action, as the slightly negative pressure as the bellows rise is required to operate the Stott valve

Wave form

There have been various theoretical and practical studies with regard to the optimum wave form to be used in I.P P.R intratracheal method of artificial respiration. It is accepted that positive pressure in the air passages interferes with the venous flow to the heart, and therefore the inspiratory phase must be kept as short as possible, while the pressure during the expiration phase must fall at once to atmospheric pressure A phase of negative pressure during expiration might provide a further improvement, but this adds considerably to the complexity of the respiration pump

In practice, the chief difficulty is to force sufficient air through the tracheotomy tube in the time available This requires a high flow rate from the onset of the inspiratory phase, and the dropping weight of the Radcliffe pump is specially effective on this score (see Fig 16) The diameter of the tracheotomy tube is the chief hindrance to adequate air-flow, so the largest practicable size of tube must always be used

Another promising design of respiration pump depends on an electric blower for positive pressure with full mechanical control of the valves, as well as of the wave forms. The type is incorporated in the Monaghan cuirass respirator *

Improvements are constantly being effected in the design of

* J J Monaghan Co, Inc, Denver 4, Colorado, U S A

respiration pumps, and developing trends in design will not be considered further in these pages.

Spalding (1955) and Spalding and Young (1955) have recently investigated the various factors such as pressure of delivery, rate of operation and duration of inspiration, which influence the efficiency of the artificial respiration by I.P.P.R. From these it



FIG 16.—Wave form taken at trachea with a condenser manometer, with Radcliffe Pump operating at 20 per minute

Rapid rise in pressure at start (arrow) of inspiration is a feature of this pump

is clear that the most effective method of increasing the minute volume of air received is to increase the pressure of delivery. Increasing the rate of respiration in much less effective. It should also be emphasized that under conditions of circulatory failure, the duration of inspiration should be kept as short as possible in order to minimize the obstructive effect the air pressure exerts on venous return to the heart Thus, it is important that slowing of the respiration rate should not also result in slowing of the rate of delivery of air to the lungs.

CHAPTER VIII

MANAGEMENT OF INTERMITTENT POSITIVE PRESSURE ARTIFICIAL RESPIRATION (I.P.P.R.)

THIS method of artificial respiration has many advantages for difficult cases, and may be adopted when treatment in a tank type of respirator encounters dangerous complications The simplicity of the apparatus makes it very suitable for transporting paralysed patients by road or by air, and from the nursing point of view the care of the patient is greatly simplified as regards access to the patient. There is, however, one serious disadvantage, and that depends on the tracheal secretions which require constant attention, and if the coughing muscles remain paralysed it will be very difficult during convalescence to wean the patient from the tracheotomy tube

However, I P P R has three noteworthy advantages (Crampton-Smith *et al*, 1954) first, a cuffed tube inserted through a tracheotomy wound separates the pharynx from the trachea so that there is no danger of inhalation of foreign material even if the patient vomits, second, it permits secretions to be aspirated readily from the trachea and bronchi, third, it provides a route for artificial respiration with the attendant advantages, compared with respiration in a tank, of ready access to the patient and of low cost of apparatus (The total cost of all the items in Fig. 14 (*b*) is about £120)

TRANSPORTING THE PATIENT

A patient with paralysis may develop respiratory embarrassment with little warning, and this may happen when the patient is at home or in a hospital which has neither the equipment nor the organization to deal with this condition This fact has in the past militated against the formation of special units for these patients, but it now appears that it is relatively simple to transport them Any unit intending to treat cases of this type must be prepared to send out a team, consisting of an anæsthetist and a

physician, to provide for the safe transport of the patient. This team must be prepared to intubate the trachea with a cuffed endotracheal tube under either local or general anæsthesia, and to provide a portable source of I.P.P. respiration and of suction The Oxford sucker-inflator unit * has proved to be very suitable



FIG 17.—Oxford sucker-inflator unit.

This contains two valves, one (high pressure) for suction (foot operated), and the other (low pressure) for lung inflation

for this purpose (Fig 17). This unit includes a high-pressure valve for suction purposes and a low-pressure valve for manually operated I P.P R.

The requisite equipment can be carried in any car and should be kept ready for immediate use It will often be unnecessary to intubate the patient for transport, but it is nevertheless essential

* Supplied by M I E Ltd, 12 New Cavendish Street, London, W 1.

for the anæsthetist to travel with the patient in the ambulance and to be prepared to intubate if necessary.

For transport, we prefer intubation through the mouth to tracheotomy, since it enables the patient's condition, and therefore the need for tracheotomy, to be reassessed after a period of satisfactory ventilation. Moreover, if tracheotomy is required, a formal and unhurried operation can most easily be performed in the respiration unit by a surgeon experienced in this operation Tracheotomy must not, however, be unnecessarily delayed, owing to the danger of ulceration of the larynx if an endotracheal tube is left *in situ* for more than a few hours.

When the patient has either an endotracheal tube or a cuffed tracheotomy tube inserted, the Radcliffe Respiration Pump may be used for transport, using the 12-volt motor (Fig 14 (*b*)), and under these conditions there is no limit to the distance the patient can be moved by air, sea or road (Harries and Lawes, 1955)

Though oxygen or other gas can be added to the Radcliffe Respiration Pumps, they normally use room air which is warmed and humidified to 100 per cent saturation before delivery. Many machines and devices have also been made which rely for their motive power on cylinders of compressed gas (Bang, 1953, Macrae *et al*, 1953, Pask, 1953, 1955, Engstrom, 1954)

Humidifier The value of humidification to keep secretions fluid has been emphasized by Lassen (1953) It is impossible to produce humidification that in any way simulates that obtaining in the normal trachea, unless the humidifier also warms the air and is placed between the respirator and the patient. The simple apparatus (Fig 14 (*b*)) described by Marshall and Spalding (1953) has proved satisfactory When it has been in use, secretions have remained moist and were readily removed by aspiration When the patients were being weaned from the respirator and were breathing spontaneously through the tracheal tube, sticky secretions sometimes occurred, and the patients complained of discomfort and difficulty in breathing, which was relieved by further humidification To obviate this a plastic bag was placed loosely over the free end of the tracheal tube, and the pump was used to blow humidified air into it This device enabled the patient to breathe warm humidified air mixed with room air and has facilitated the weaning phase

Expiratory Valve. The most important feature of an expiratory valve is that it should permit perfectly free expiration; for, if the tracheal pressure does not fall to atmospheric in expiration, there is a deleterious effect on the circulation (Werko, 1947; Cournand *et al.*, 1948; Motley *et al.*, 1948). For this reason any form of expiratory apparatus which depends for its proper functioning on introducing resistance cannot be regarded as satisfactory. The "flutter" valve* (Fig 15) has proved adequate, but a mechanically operated valve will probably prove to be better.

Pressure gauge. The use of a pressure gauge † close to the tracheostoma (Fig. 14 (*b*)) has proved of special value because it provides a continual visual check on the working of the I.P.P.R. system, but it must be placed at a raised position to avoid water running into the mechanism. It shows that in inspiration the maximum safe intrapulmonary pressure is not being exceeded, and in our experience pressures above 20 cm. water are rarely required. It also gives positive evidence that the expiratory valve is opening freely. Moreover, a change in the readings gives an early indication that something is wrong. A rise in pressure suggests pulmonary complications, and a fall, a leak in the system, either outside the patient or beside the tracheal cuff In either case early treatment will avoid serious mishaps.

Tracheal tube. We have used cuffed endotracheal tubes cut to a length of about 4½ in. At the external end a McGill suction union is connected, and through the opening in this, which is normally kept occluded, aspiration can readily be applied. The lower end of the tube is also cut short immediately below the cuff, with the minimum of bevel, for this end reaches almost to the carina and, if too long, can easily enter the right bronchus, occluding the left For the same reason tracheotomy should be as high as possible *The cuff is deflated briefly every four hours* to protect the tracheal mucosa, and a fresh tube is inserted every three or four days

Ventilation The dangers of inadequate ventilation with hypoxia and retention of carbon dioxide are well recognized.

* Made by Owen Mumford & Co, Green Place, Abingdon Road, Oxford
† Made by K D G Instruments Ltd, Purley Way, Croydon

Those of over-ventilation are not at present well defined There are extremely sensitive mechanisms in the normal person which prevent over-ventilation, and if it occurs it produces profound alterations in body electrolytes It therefore seems highly unwise to induce over-ventilation in a sick person, whose ability to compensate may be impaired or who may not be in a condition to withstand a change in ionic balance The importance of maintaining electrolyte equilibrium has been increasingly appreciated in recent years in other serious conditions—e.g, diabetic coma, the post-operative state, and severe injury—and should not be neglected in this instance.

It is not easy to assess when adequate ventilation is being provided, and the patient's subjective sensations, often a most useful guide, are not available in the most difficult instances—i e, in the acute stage, when the patient may be unconscious or incapable of co-operation, and in children. Objective criteria are therefore desirable

We have measured in a spirometer the volume of air expired each minute, and have found this a valuable procedure. Two girls aged 16 and 17, of slight build, required 7–8 litres per minute, whereas a heavily built labourer required about 10 litres per minute In all our cases the respiratory rate used was 16–20 per minute A minute volume that is approximately correct can thus be assured, and it can be adjusted in the light of the patient's progress Slight under-ventilation can be detected by a gradual rise in blood pressure, and over-ventilation by a rise in the urinary pH. The conclusions drawn from these estimations may be confirmed by investigating the blood chemistry

Pulmonary complications Patients with bulbospinal paralysis are extremely liable to pulmonary complications since they cannot cough and rid themselves of their secretions Prophylaxis and early treatment are essential, and the following prophylactic measures have been adopted

(1) Two-hourly changes of posture from one side to the other, these often loosen secretions so that they can be easily aspirated

(2) Four-hourly vibration and percussion by a physiotherapist, these to a considerable extent took the place of the normal cough in removing secretions (Fig 18)

(3) Aspiration of trachea and bronchi with Tiemann's catheter, whenever secretions are present This catheter is rather stiff and has

a curved tip by which it is possible, with the patient lying on, say, the right side, to pass the catheter into the bronchi of the left (uppermost) lung which is receiving physiotherapy.

(4) Hydration of the patient and humidification of the inspired air. In this way the secretions are kept fluid and easy to aspirate.

(5) Antibiotic therapy.



FIG 18 —The all-important chest physiotherapy with appropriate body posturing.

This patient, who is recovering from acute infective polyneuritis, still has a tracheotomy tube The Radcliffe pump maintained respiration for four weeks before the muscles recovered sufficiently

In the presence of established pulmonary collapse these measures were intensified. If they failed, bronchoscopy was performed, but the need for this became less and less frequent as experience was gained.

Although bronchoscopy through the tracheostoma is easy, it proved impossible to ventilate an apnœic patient adequately

through a bronchoscope in this situation, because of leaks round the instrument Bronchoscopy was therefore performed through the mouth, with the tracheostoma temporarily occluded Thiopentone anæsthesia, with or without relaxants and with intermittent inflation with oxygen, proved satisfactory.

Blood Pressure

Lassen (1953) found frequent records of the blood pressure a useful guide to correct ventilation, since carbon-dioxide retention is quickly reflected in a rise in blood pressure. Although in some circumstances the significance of changes in blood pressure is difficult to determine, in most instances valuable information is obtained from half-hourly records

Biochemical Control

Feeding With a cuffed tube in the trachea the bronchial tree is separated from the pharynx, and the dangers and deficiencies of parenteral nourishment, which may have to be faced in some cases of dysphagia without respiratory weakness, can be avoided Polythene nasal tubes are less irritating than rubber and require changing less frequently In an illness of the severity and duration of most cases of bulbospinal paralysis it is important that nourishment be adequate Not only must the intake of fluid and calories be satisfactory, but also the diet should be mixed and contain as much protein as can be metabolized, judged by the blood-urea level We have used the diets described by Higgins *et al* (1954), which provide 2200 calories or more daily They were diluted with water or with Ringer-Fischer's solution as biochemical investigations indicated

Drugs Antibiotics are required in full doses Sedation is necessary, especially in the early stages, and chloral hydrate and phenobarbitone have both been used

Nursing

A severely paralysed patient requires a great deal of careful nursing, and I P P R allows completely free access to the patient,

in striking contrast *to artificial respiration in a tank respirator.* Patients must be nursed on a bed that can be easily tipped They will often be slightly head down, and therefore care of the skin over the acromioclavicular joint is especially important Since it is not one of the classical pressure areas it is liable to be overlooked.

At least three nurses are required to turn a badly paralysed patient having I.P.P.R., and during the acute stage it is desirable to have a doctor attending to respiration during turning, and readily available at all times.

We are satisfied that several of our cases could not have been kept alive in our hands by any other method, and now incline to the view that the Copenhagen method should be used without hesitation in cases of pharyngeal paralysis with respiratory insufficiency due to either paralysis of respiratory muscles or to the development of lung complications. Clearly, therefore, this method should be available in the special centres

It should, however, be made perfectly clear that the Copenhagen method is dangerous in the absence of close and experienced nursing and medical supervision, and we have found that an experienced doctor must be at hand day and night during the early critical days. This method solves some problems, but introduces others and greatly increases the number of things that can go wrong. For example, any of the following may happen:

(1) Undetected secretions may accumulate in the trachea and bronchi to a dangerous degree.

(2) The pump pressure may suddenly fail owing to a kink in the tube or a connexion blowing off or a failure in the pump.

(3) The expiratory valve might fail to operate so that the chest becomes progressively inflated.

In addition to such mechanical faults, sudden changes in the blood pressure or consciousness may indicate that something is going wrong

However, we have become convinced that the *Copenhagen* method is most valuable in certain cases if adequate skilled supervision is available in a special unit Relatively few such units are required provided that an anæsthetist is available to transport the patient

Disadvantages of Copenhagen Method

The treatment of respiratory insufficiency by I.P.P R should not, however, be embarked on without careful preparation, as the method by itself introduces certain hazards. It is in the first place obvious that an intratracheal tube introduces infection into the air passages with the production of excessive secretions. The dangers of infection can be dealt with adequately in the acute stage with antibiotics, the skilled use of the sucker and chest physiotherapy; but if many of the trunk muscles remain permanently paralysed great difficulties appear when attempts are made to wean the patient from the tracheotomy tube It is paralysis of abdominal muscles which presents special problems, as coughing depends chiefly on these. When therefore attempts are made to wean the patient from the tracheotomy, it is necessary to re-establish the close night and day supervision used in the acute stage Special reliance must then be placed on prolonged postural drainage, and chest physiotherapy to get rid of secretions when suction through the tracheostome is no longer possible

Mechanical Coughing

At this stage, the American Exsufflation machine (see Beck and Barach, 1954) is of value, for it reproduces the wave pressure form of a normal cough Thus it cycles from a positive mask pressure for inspiration to a considerable negative pressure with great suddenness and thus reproduces the expulsive effects of the normal cough There are, however, sometimes difficulties in using this machine effectively.

The careful planning and discipline required of this matter has not yet been fully worked out, the potential dangers may be appreciated from the case of a young man who developed a lung infection while the tracheostomy wound was closing, and who during bronchoscopy died suddenly

CHAPTER IX

TREATMENT OF RESPIRATORY PARALYSIS IN SPINAL CASES

LASSEN, in the 1952 Danish epidemic, used tracheotomy and I.P.P.R. for most cases of respiratory insufficiency, and thus provided an important addition to the methods available, but it is evident in retrospect that the possibilities of the use of other methods for certain groups of cases were not adequately explored. Thus the use of postural drainage alone is, in skilled hands, very effective when the throat only is paralysed, while in cases of pure spinal paralysis of respiration the tank respirator should probably be used first.

It is, however, becoming evident that for cases which are not being handled safely by either of these older methods, I.P.P.R. with a cuffed tracheotomy tube will save lives which will otherwise be lost. I.P.P.R. should not be the first choice in those who are likely to be permanently in need of some mechanical assistance with respiration. For even if they recover quite a comfortable figure for vital capacity, and yet, owing to paresis of the abdominal muscles, never recover a good cough, then it may prove to be impossible to wean the patient from the tracheotomy.

Thus, an adult patient who has been treated in a tank respirator for several weeks can, after recovering a vital capacity of 800–900 ml., lead quite an active and useful life if the state of the limbs permit. If, however, he has been treated with a tracheotomy and his abdominal muscles are weak, the inevitable tracheal secretions make it very difficult to dispense with the tracheotomy or the nursing care required to carry out repeated tracheal suction. Thus, such a patient will during convalescence do much better *if he has never had a tracheotomy.*

TANK RESPIRATORS

Many types of breathing machine have been designed, but the original box or tank type gives more efficient action than

others, as indicated by the measured volume of tidal air achieved by the machine in paralysed patients (Bourdillon *et al.*, 1950)

In this type of respirator the whole body except the head is enclosed in a box to which negative pressure is applied intermittently. This causes very effective respiration, not only by raising and expanding the chest, but also by raising the abdominal wall, and thus pulling the diaphragm gently downwards. A large tidal air can be obtained in this way, and the negative pressures, being widely applied, are comfortable and gentle in action.

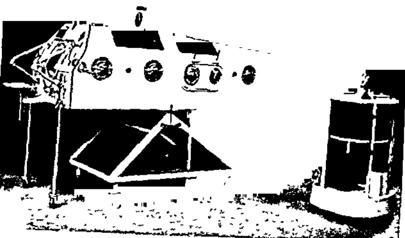
It is clear that there is as yet no substitute for the box or tank of respirator, but many ingenious improvements have been devised which make for increased effectiveness, safety and comfort (Bower *et al*, 1950) For example, the rate of respiration and the adjustment of both positive and negative pressures are now better controlled, the best shape for the wave-form caused by the pressure changes has received much attention, quick methods of tilting the patient for postural drainage, an alarm system for failure of the suction pressure, improved comfort for the collar neck-seal, and external control of level of upper end of stretcher, are among the many improvements developed.

A working party on Breathing Machines, of the Ministry of Health, London, has been concerned with fostering some interesting developments in tank respirator design, and in connection with this many have contributed, especially the work of Bourdillon *et al*, (1950)

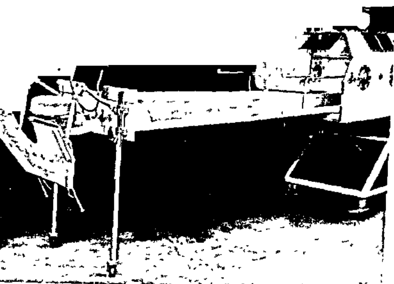
Thus a recent design of respirator by Siebe-Gorman Ltd, contains many improvements (Fig 19 (*a*) and (*b*)), including a "split front" which considerably simplifies care of the patient.

The new Coventry * type (Fig 20) also constitutes an important simplification of design, and even further simplifies nursing problems This "alligator type" has many obvious advantages, including the fact that it is considerably less expensive than other makes The division of the collar into two halves is a special help towards nursing, and two nurses only are required to put the patient in such a machine

* Manufactured by the Cape Engineering Co, Ltd, Warwick, designed by Captain G T Smith Clarke M I Mech E



(*a*)



(*b*)

FIG 19 (*a*) and (*b*) —A recent respirator design by Siebe-Gorman Ltd

The divided front facilitates nursing attention and simplifies the process of moving the patient into the machine

Failing respiration

Not long ago the usual practice regarding respiratory failure was to wait until the patient was severely anoxic before using a respirator. This attitude, however, increases the danger of atelectasis and is inconsistent with the general attempt to rest muscles during the acute stage of the disease. There is, therefore, much to be said for early respiratory treatment before the patient becomes seriously embarrassed, but such treatment should be provided by nurses trained to transfer a patient into a respirator without inflicting either physical or psychological trauma. Two nurses may be required for one patient, but to put a patient into some respirators, three or four additional people may be required. However, for the Siebe-Gorman respirator with split front and the new Coventry respirator two nurses may suffice.

Putting the patient in a respirator

The early signs of respiratory weakness have been described on p. 39 and, *provided there is no paralysis of swallowing*, there should be no hesitation in providing respirator treatment if it can be properly supervised.

The first task is to move the respirator near to the patient, and as some respirators when closed look somewhat like coffins, the patient should be screened from these preparations, indeed there is no need for him to view the respirator at all. He should then be told (if old enough) that we wish to give his breathing muscles an extra rest for a time, and are going to lift him on to a special stretcher which does this, and that he should find it comfortable. The trained team can then proceed with the task of transferring him to the respirator. If the staff has little experience of respirator treatment they should first practise on one of themselves.

Initial pressures

When the patient first goes in a respirator he will be grateful for a few deep breaths at a high negative pressure. Soon, however, the pressure should be reduced to the minimum speed and pressures required for comfort.

In the absence of special apparatus it is often instructive when

the patient is asleep to lower the suction pressure slowly until he becomes restless, and then raise it a little above the restless level; this gives a useful indication of the comfortable pressures while avoiding the risk of overventilation.

The nurse may make a habit every thirty minutes or so of shutting the valves to give two or three extra deep breaths

The patient will often ask for the suction pressure to be increased. This request should be acceded to if only to give the patient confidence, first with several full breaths and then with a pressure slightly above the one previously used—this can often be lowered again if considered desirable without the patient realizing that he has returned to the previous pressure. The patient's judgment with regard to adequate pressures is often accurate, and, if atelectasis occurs, greater pressures will be required and indeed demanded by the patient if still conscious.

The dangers of overventilation are insidious, so that a slight measure of underbreathing is often preferable, especially in patients who have been put in the respirator merely to give the muscles a rest. On the other hand, a slight degree of cerebral hypoxia will quickly cause disturbance of consciousness. There is a reasonable prospect that with the wider use of oximeters and CO_2 meters there will now be better control of ventilation in these cases.

Nursing care

The details of nursing care for respirator cases can only be learned properly at the bedside, but the publication *Nursing* (1948) and the book by Stott and Fischer-Williams (1955) will be found useful. Mobile teams of nurses and doctors experienced in respirator treatment are needed to assist with epidemics and with sharp outbreaks which may occur in small communities.

A patient who is seriously ill with poliomyelitis, whether in a respirator or not, should never be left alone during the early critical days Ideally the nurse should hear every breath, so that a tendency to choke or vomit can be dealt with at once with sucker and posturing The nurse should not hesitate to change the patient's position frequently Children, and indeed adults, should on no account be subjected to the terrifying experience

of being left alone in a room in a respirator with no means of summoning help

Safety devices Various devices can be used to increase the safety of respirators. In the first place, every respirator should be fitted with an alarm system which will ring when negative pressures fail When patients must be left alone, they should have a bell-push which they can operate with whatever muscle is still acting Movement of the chin may be used for this purpose

A laryngeal microphone (Stott, 1953) connected with a loudspeaker has been found invaluable in the handling of cases liable to get mucus in the pharynx or larynx This is specially so in respirator cases in which the noise of the respirator prevents the staff from hearing the patients' breathing without some artificial aid

Listening to the mouth or larynx with a binaural stethoscope also gives much information regarding the flow of air and the presence of bubbly secretions

[illegible]

F [illegible]
s [illegible]
nurse should always be ready to tilt the respirator steeply with the head down to prevent inhalation of secretions or vomit Vomiting is particularly dangerous as the respirator suck cannot be resisted, and without adequate postural drainage inhalation of vomit is almost inevitable

Abdominal distension The development of abdominal distension in a respirator-treated case is generally due to acute gastric dilatation and is a complication likely to be fatal if not vigorously treated One probable cause is the development by the patient of a tendency to swallow air, and if this is done during the inspiratory phase of the respirator, it is possible that the negative pressure will suck air into the stomach If a distended abdomen is allowed to pass unnoticed, the first symptom may be the regurgitation of mouthfuls of black gastric contents containing altered blood Circulatory collapse may follow, especially if some of the vomit is sucked into the lungs by the respirator's action. In any case a stomach tube must be passed, and an attempt made to empty the stomach by gastric suction of the air

and altered blood which it contains While the patient is being given food or drink to swallow in a respirator, the opening of a port for a few moments during the actual act of swallowing may prove to be helpful. The use also of positive pressure during the expiration phase is probably beneficial in preventing gastric dilatation. Patients who are noticed to be swallowing frequently must be encouraged to refrain from this. They should be taught to swallow during the expiration phase. Retention of urine must not be overlooked, and catheterization can be readily carried out by using two ports of the respirator, one for each arm—the bare arm of the doctor or nurse seals firmly with the rubber aperture in the port.

Fæcal masses in the rectum may require manual removal Enemata may be given, but medicinal purging is better avoided

Ventilation

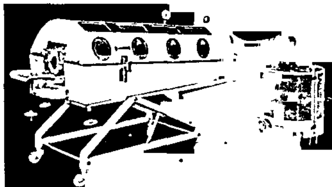
While the lungs are healthy, hyperventilation may easily be produced. Pressures of about minus 16 cm. and plus 5 cm of water, at a rate of 16 cycles per minute are often suitable for older children and adults, provided the lungs are reasonably healthy. When one lung is collapsed, a much higher rate may be required, up to 35 cycles per minute, and even higher in infants.

The airways must be kept clear by suction and posturing Frequent changes of position, including the semi-prone posture, can be obtained in the newer respirators and are highly advantageous The breath sounds at the larynx should be frequently listened to in order that pooling of secretions may be recognized in time The nurse may use a stethoscope for this, but a throat microphone amplified by a loudspeaker is preferable (Stott, 1953).

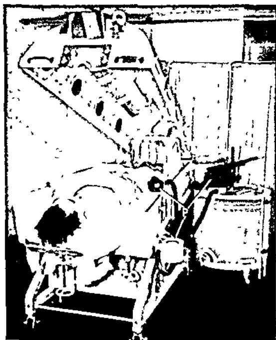
The adequacy of oxygenation may be checked by an Oximeter,* but frequent blood-pressure readings should also be taken, as a rise of blood pressure is an early sign of CO_2 retention.

Every precaution should be taken to avoid atelectasis, and daily lung X-rays may be desirable. Bronchoscopy may be required, while any loss of functioning lung tissue may necessitate increasing the pressures and rate at which the respirator is

* Manufactured by Stanley Cox, Ltd



(a)



(b)

FIG 20 (a) and (b) —The new "Coventry" respirator in use with attachment for positive pressure breathing (P)

The patient (6 ft 4 in) had had experience of many types of respirator, and spoke very highly of this one

working. In cases with atelectasis the decision to do a bronchoscopy is a difficult one, for this is a formidable procedure in respirator cases, and it often achieves very little. Fortunately many areas of atelectasis clear up well spontaneously.

A good respirator is so constructed that most of the nursing can be carried on without opening the respirator, but in addition it is essential that an efficient form of positive pressure breathing be available to keep the patient comfortable when the respirator is opened. *The Oxford Inflating Bellows (Macintosh, 1953)* or a low-pressure oxygen valve (Macintosh and Pratt, 1939) are convenient for this purpose and, if operated by hand, can be made to synchronize with the rhythm of the respirator before the machine is opened. A mechanically operated positive pressure pump may be very useful, especially if, as in the Coventry Respirator, it synchronizes with the main machine (Fig. 20)

The well-known American-made Emerson respirator has a plastic dome to close over the head and through which positive pressure can be applied. This, however, causes discomfort in the ears and interferes with the patient being turned: a well-fitting mask to the face is generally preferable. The Radcliffe Respiration pump, and the pump described by Beaver and Byford (1954) have also been used successfully to maintain respiration through a mask or mouthpiece when the tank is open. The patients learn to hold a suitable mouthpiece between their teeth as described by Beaver and Gilliatt (1954)

There is thus no excuse now for permitting the torturing periods of anoxia which respirator patients were at one time forced to endure when the respirator was opened for nursing purposes. However, it is always helpful to increase the operative pressures for a minute or two to overventilate the patient before any procedure such as changing the type of respiration is carried out

Weaning from the respirator

Weaning from the respirator presents no difficulties if it is properly handled and the muscles have sufficient strength to maintain an adequate tidal air. The use of a spirometer will often correct the all too common assumption that because a patient is frightened of being without artificial respiration, therefore his reluctance is neurotic! Many cruel injustices of this

kind occur, and on one such occasion the forceful discontinuing of the respirator led to ischæmia of the retina and brain, causing transient blindness and mental confusion

The first step in weaning from the respirator should be merely a prolongation of a method of testing the unaided respiratory capacity The respirator motor is kept running, and after explaining to the patient what you want him to do, one of the respirator ports is opened and the patient asked to count This test can be done by an intelligent nurse, and the gradual improvement in counting is encouraging to the patient After the test, a few deep breaths at full pressure give quick relief to the patient Opening one of the ports has, of course, the same effect as turning off the motor, but is less frightening, for the patient realizes that the suction can be instantaneously re-established. One common difficulty in severe cases is that respiration may have to be carried out largely by the sternomastoids, and that while in a respirator these muscles cannot contract comfortably owing to pressure by the collar seal. The severity of respiratory paralysis can sometimes be judged by the immediate action of the sternomastoids when respirator action is inoperative

Occasionally, when the patient has been persistently overventilated, the "setting" of the respiratory centre is altered so that the patient is only comfortable when his blood CO_2 level is below normal. This can be slowly corrected by reducing ventilation

At one stage in weaning the patient can breathe during the day, but needs help to enable him to sleep, and for this purpose the Cuirass-type of respirator or the Bragg-Paul pulsator are often required for long periods, and are much used by these patients in their own homes Patients at this stage often have a vital capacity of 700–800 ml, but this is dependent to some extent on the action of accessory muscles which do not work very well during sleep Psychological factors play a part, but there is little to be gained in trying to persuade these patients that they are using the machines unnecessarily The patient's judgement in this matter is usually correct Weaning may again be assisted by slowly reducing the cuirass pressures during sleep

Cuirass-type respirators enclose only the chest and abdomen (Fig 21), leaving the limbs and the neck quite free. The chief action is on the abdominal wall, and thus on the diaphragm which is swung up and down quite powerfully.

They are not suitable therefore for use in the acute stage of the disease. As regards efficiency, there is as yet no substitute for the tank-type machine, but the cuirass respirator is of special value in some chronic respirator cases (Kelleher, Kinnier Wilson, Russell, Stott, 1952)

Appliances which compress the chest intermittently like the Bragg-Paul pulsator are also sometimes useful in recovering cases, but the volume of tidal air obtained is also quite inadequate for



FIG 21 —Cuirass respirator in use.

This patient 6 months after the acute illness had a vital capacity of 800 ml and was then able to go home each week-end with this machine to assist sleep at night

cases of severe paralysis. This apparatus is sometimes of value in chronic respirator patients whose chests have become rigid in the inspiratory position as a result of the prolonged negative pressure treatment.

The cuirass has another advantage, for it assists venous return from the lower limbs The tank respirator, on the other hand, hinders venous return in the same way as does I.P.P.R.

Phrenic nerve stimulation has been suggested as a method of artificial respiration by Sarnoff (1948), but this method is usually quite inappropriate for paralytic poliomyelitis, as this will only encourage and hasten the Wallerian degeneration of the phrenic nerve which it is our chief purpose to avoid. In any case, when

the phrenic nerve nucleus is destroyed, the phrenic nerve ceases to exist within 2 to 3 days, and this degeneration is hastened by electrical stimulation (Cook and Gerard, 1931).

The same objection applies to attempts to stimulate the intercostal muscles electrically, as their electrical response depends largely on the integrity of the nerve supply.

However, Macaulay (1954) has reported cases in which apnœa was due to failure of the respiratory centre, and in which

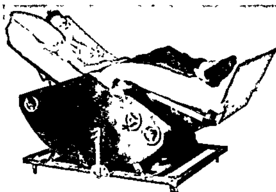


FIG 22 —Rocking bed* in use (from Schuster and Fischer-Williams)

respiration has been maintained by phrenic stimulation In this rare type of case there is no paralysis of the diaphragm so that this method becomes more rational However, the other methods of artificial respiration are also effective in this type of case, so the need for the phrenic method is still not obvious

The Rocking Bed (Fig 22) has proved to be a useful addition to treatment in cases of respiratory paralysis It was first advocated for this purpose by Wright (1947) and is developed from the well-known method of artificial respiration advocated by Eve (1932) Schuster and Fischer-Williams (1953) have confirmed its usefulness The gas meters which are now available instead of water spirometers can be used without difficulty to measure the effect on the tidal air of rocking the patient The increase in tidal air effected may only be 100–150 ml, but even

* Now manufactured by Cape Engineering Company, Ltd, Warwick

this relieves the strain on the paretic muscles, and also has a tonic effect on the patient's circulation and kidneys.

The usual practice is to start using the rocking bed for short periods (5–10 min.), when the patient is able to breathe without assistance for 10–15 min. Often the rate of improvement in vital capacity is considerably accelerated by this exercise, and after the patient has learned to breathe with the machine, he may be able to use it for many hours of the day and night.

During convalescence the development of even a mild chest infection many necessitate resumption of respirator treatment for a few days or weeks.

With improved methods of treating the acute stage a certain number of patients will be kept alive who have extreme degrees of respiratory paralysis and who will require artificial respiration for the rest of their lives

In one such case after twelve months on I.P.P.R. there is no detectable recovery of the respiratory, or indeed of the other spinal muscles.

Glosso-pharyngeal Breathing

Some patients with extreme degrees of respiratory paralysis have learned to press mouthfuls of air down into the lungs by action of the throat and tongue muscles (see Spencer, 1954) Apparently it is possible by means of this manœuvre to inject a series of mouthfuls of air into the lungs until they become well distended, after which the larynx is relaxed to permit expiration

Respirator Units

Respirator Units are planned to save life in the acute stage by preventing respiratory insufficiency, but after this has passed *the rehabilitation of these severely paralysed patients* presents a new series of problems, and for these a limited number of *respirator units* are required These should each provide for 6 to 12 respirator cases They should be provided with all the devices for weaning from the respirator, and at the same time would provide tolerable conditions for the hopeless case.

CHAPTER X

CARE OF MUSCLES AND JOINTS

CARE of the muscles and joints during the paralytic stage of the disease is sometimes a simple matter, but on other occasions it presents considerable difficulty.

As the paralysis appears, the patient must be persuaded by every possible means to avoid voluntary muscle activity *The disastrous but all too common reaction of a robust patient that he must keep his limbs moving till they will move no more must be anticipated and countered effectively by explanation* On the other hand, orthopædic attempts to enforce muscle rest by the use of frames are highly undesirable at this stage of the disease Not only may this seriously complicate the handling of respiratory paralysis should it develop, but there is no evidence that rigid splinting does in fact result in the desired physiological rest of the muscle.

Pain may be associated with reflex contraction (" spasm ") of non-paralysed muscles, and contractures quickly form Every effort should be made in the acute stage to relieve pain and promote physical and mental relaxation It is not known which drugs can be used with most safety in the acute stage, but barbiturates and Tab Codein Co seem to be satisfactory, while hot packs often give much relief The study of drugs which relieve this muscle tightness requires further research Gentle passive movements should be incorporated in the process of examination from the first day of the disease, and this quickly shows which muscle groups, if any, are likely to cause trouble.

" Muscle spasm ", muscle shortening and contracture

The term " muscle spasm " was introduced by Sister Kenny, but it consists not of an active spasm in the neurological sense, but of a protective fixation of muscle in moderate contraction very similar to that observed in relation to a fractured bone or inflamed joint In poliomyelitis, however, this fixing attempt by

the muscles may act very unevenly owing to asymmetrical paralysis, and a joint may thus be pulled *into a progressively* deformed posture which, if neglected, later merges into a firm contracture of the muscle concerned

This is not the whole story, however, for all muscle tissue shows a strong tendency to shorten whether it is paralysed or not, and it is partly for this reason that the full range of joint movement should be established as soon as possible (as indeed Sister Kenny advocated for other reasons).

Generally the muscles which tend to shorten are those which are strongest, thus the pectoral muscles shorten quickly in deltoid paralysis, and the shoulder-raising muscles (including the trapezius) shorten quickly when the shoulder-fixing muscles are paralysed, especially if the patient is kept lying down, so that the normal gravitational pull downwards is inoperative.

This shortening of the strongest of opposing muscle groups led to the entirely erroneous idea that shortening (tightness) is an important *cause* of weakness of the opposite group, clearly this shortening is not a cause but a *consequence* of the weakness opposing. This fact is very apparent when other forms of flaccid paralysis with muscle imbalance are studied Such muscle shortening may, however, interfere with exercises to increase the strength of the paralysed group, and for this purpose spring devices to assist the weak muscles are helpful.

This muscle shortening is often wrongly called spasm, yet its true nature must be recognized, for too vigorous attempts to stretch shortened muscles will damage the muscle fibres and may even precipitate a calcifying myositis.

Here is sometimes a danger for the hot-pack enthusiast, since the hot-packs raise pain thresholds and may enable the physiotherapist to stretch too hard and too soon.

This muscle shortening, although well seen in the strongest of opposing muscle groups, will also appear in completely denervated muscles if they are left in a relaxed position Thus, in a respirator case with complete paralysis of all upper limb and shoulder muscles, shortening will quickly develop in muscles relaxed by the patient's posture, thus the pectorals and biceps often shorten severely as do the extensors of hips and thighs It is of course ridiculous to call this spasm, for these muscles are denervated and permanently useless.

Dangers of maintaining relaxation of paralysed muscle

Here we encounter the long-standing medical view that a denervated muscle should be kept in a relaxed posture. This idea is, however, based on a misconception, for if a denervated muscle is allowed to shorten as a result of this treatment, then it becomes vulnerable to later attempts to regain the normal range of movement Thus, removal of a long-maintained abduction splint at the shoulder may be followed by weakening of the deltoid muscle. This has often led to the conclusion that the abduction frame is necessary, whereas it is more probable that this effect was a consequence of the splinting having allowed the weakened muscle to shorten and thus become easily damaged Thus, it should be understood that the range of movement of a paretic muscle should be maintained, and here no doubt lies the key to some of the successes of the Kenny methods. It also re-emphasizes the need for persistent and early passive movements to maintain not only the range of joint movement, but also the capacity of both the weak and the strong muscles to be stretched without harm

The muscle tightness of the acute stage generally disappears in 3 or 4 weeks in well-treated patients Muscle shortening should not be allowed to develop, but of course a gross degree of muscle imbalance may cause a lifelong struggle against deformity.

Splints

Though the dangers of constantly relaxing muscles with splints are becoming clear, they may be valuable if only used intermittently, for they may then contribute considerably towards preventing the deforming tendency of muscle imbalance This then is the true function of splints. They should not be used to keep paralysed groups of muscles continually in a position of relaxation, as this is harmful to the paralysed muscle, but they should be used intermittently to limit the deforming effects of muscle imbalance. In other words, they should be used in the important endeavour to prevent a dominant muscle group from shortening Thus, a bed board for the feet to rest on is important in the prevention of the common shortening of the calf muscles, but it is of course not enough, and passive dorsiflexion of the foot and toes carried out with all the nurses' strength (when the

early sensitivity has subsided) several times a day may be an essential part of the treatment necessary to prevent calf-muscle shortening (contracture) Weight bearing without heels on the shoes also plays a helpful part in keeping the calf muscles stretched.

Nurse and Physiotherapist

The commonly accepted view that physiotherapy should only be done by physiotherapists is harmful to the treatment of poliomyelitis, for few physiotherapy services can possibly provide the four-hourly passive movements required The physiotherapist should recognize this situation, and instruct her nursing colleagues accordingly.

Hot packs. The use of " hot packs ", as advocated by Sister Kenny, has received so much publicity that some might be led to think that their use reduces the amount of ultimate paralysis There is, however, no reason to suppose that the life of a single nerve cell has ever been saved by the use of hot packs.

The main use of the hot pack is to relieve pain, and thus reduce the muscle spasm which is aggravated by local pain In this connection it should be emphasized that muscle spasm (as distinct from muscle shortening) does not, and indeed cannot, occur in muscles whose spinal cord motor cells have already been destroyed, so that in the acute stage of the disease muscle spasm is a good sign as far as the recovery of that particular muscle is concerned The relief of pain and reduction of spasm by hot packs has led to the false idea that hot packs have saved a muscle (in spasm) from paralysis ; whereas in fact the muscles in spasm cannot have already been paralysed (i e. denervated).

As has just been pointed out, however, spasm of unopposed muscle groups quickly leads to muscle shortening, and must be countered with increasing vigour after paralysis has ceased to spread Hot packs may be useful here, although their need often indicates that the patient has been allowed to lie in one position for too long a period Where frequent gentle passive movements and changes of position are carried out from the onset of the disease, muscle spasm and shortening are rarely troublesome

The main benefit derived from the Kenny treatment was that it provided an effective counter to an unreasonable and unphysiological orthopædic tenet that paralysed or paretic limbs should

be rigidly splinted. The rightly famous Liverpool School of Orthopædics had for over thirty years taught that a paretic muscle should be splinted (Seddon, 1952). This "principle" has long since been discarded in most nerve injury centres, but unfortunately it still persists to some extent in the treatment of poliomyelitis. It is not surprising, therefore, that the Kenny treatment has, in a certain type of case, been very successful, though the Kenny treatment is based on ideas which are unacceptable to modern neurophysiological knowledge

In the writer's experience acute paralytic poliomyelitis can be handled very well without hot packs, indeed, if there is any shortage of staff, the application of hot packs will divert precious effort, and lead to the neglect of much more important tasks

Passive movements

On the other hand, passive movements are vitally important, so much so, that, as has already been stressed, the nurse should be expected to spend 2 or 3 minutes moving the limbs every few hours

Gentle passive movements should be instituted from the very onset of the paralytic phase, and indeed if skilfully carried out these greatly reduce the tendency for muscle spasm to develop.

In order to carry out passive movements of the arm and shoulder the nurse should raise the upper limbs with two hands, one at the elbow and one at the wrist Necessary movements are arm abduction and rotation at the shoulder, forearm extension, supination and pronation, wrist flexion and extension; finger flexion and extension, thumb opposition Five or ten seconds spent on each of these movements, to a degree short of pain, every few hours will pay rich dividends in the free muscle and joint movement acquired early in convalescence

For the lower limb the leg is supported by two hands, one under the knee and one at the ankle. The knee and hip are flexed and extended The hip is abducted and rotated both outwards and inwards. The leg is raised straight to the point of commencing discomfort. The foot is passively flexed, extended, inverted and everted The toes are flexed and extended. Dorsi-flexion at the ankle and toes should be carried out with all the vigour the patient can tolerate to counter any tendency to shortening of the calf muscles In the case illustrated

in Fig. 23, there was a strong tendency to contracture of the thigh flexors and plantar flexors, but this was completely corrected in less than three weeks from the onset of the illness by frequently repeated passive movements to stretch the tight muscles without any splinting.

If any muscles tend to shorten, these should also be stretched by posturing with pillows

With regard to stiffness of the back and neck, reliance may be placed on frequent changes of posture (Figs. 10, 11 and 12) Right and left lateral, right and left semi-prone. The full prone position should be used once or twice daily as this is specially valuable in the prevention of spinal deformities The prone position may be specially comforting when there is spasm of spinal muscles.

Prone lying for, say, half an hour three times a day is a vital part of the postural treatment of all patients with severe trunk and lower limbs paralysis, for it counteracts the common tendency for mid-dorsal kyphosis, and for flexion contracture at the hip —the latter is specially disabling when attempts to stand begin. During prone lying the thighs should be abducted especially if *some counter to contracture of the adductors is required.*



FIG 23 --A girl, aged 16 months, in whom "spasm" of the left thigh flexors and plantar flexor muscles was corrected by physiotherapy alone within three weeks of the onset of the illness.

Nurses should be taught by the doctors or physiotherapists *to carry out these various manœuvres in such a way that the* patient is not unduly fatigued.

In the acute stage, especially, every effort should be exerted to make the patient comfortable, and the frequent slight changes of posture which good nursing provides are of great value. Nurses and physiotherapists often seem afraid to change the patient's position in bed in the acute stage of poliomyelitis, but this outlook should be discouraged, for the more the patient lies in one position the more does he become sensitive to movement *Provided the patient is awake, small changes of position can be* made every hour or two, or more often if he asks to be moved These frequent and slight passive movements are much more important than hot packs in the avoidance of prolonged muscle spasm, and there is a danger that they may be neglected when hot packs are applied with vigour

There are of course great advantages if the same physiotherapist can treat the case in both fever hospital and rehabilitation centre.

To summarize, therefore, treatment in the paralytic stage is directed towards the avoidance of all unnecessary muscle activity, while at the same time avoiding the development of painful spasm or contractures

Frequent passive movements applied from the onset of paralysis prevent contractures and often make it unnecessary to use splints of any kind Plaster beds and frames designed to maintain the limbs and trunk in one position for long periods are still advocated by a few orthopædic surgeons, but modern knowledge *of neurophysiology sees no possible advantage in* fixation of such severity.

The handling of the acute stage is complicated by the fear of the rare spread of paralysis about a week after the main paralytic phase For this reason it is wise to discourage *active* movements for the first two weeks of the acute stage and to concentrate attention on passive movements and the avoiding of contractures in tight muscles.

CHAPTER XI

CONVALESCENCE AND REHABILITATION

THE handling of the recovering stages of poliomyelitis presents great problems, for there are many things to consider, such as:

1. How much exercise should the weak muscles have?
2. Which muscles are so paralysed that useful recovery is impossible?
3. How long should the period of bed-treatment be continued?
4. How should the deforming tendencies of muscle imbalance be countered?
5. How are weak spinal muscles to be supported?
6. When should weight-bearing and attempts to walk be started?
7. For how long is hospital treatment necessary?
8. How can the possible conflict between the demands of treatment on the one hand, and of home, education and career on the other be best solved?
9. When can the ultimate condition be accurately calculated and plans for future life prepared?
10. What special educational or training needs are required to enable the patient to make the most of his disability?

It is obvious therefore that the proper handling of these cases requires a good knowledge not only of poliomyelitis and its possible effects but also of the physiology of nerve and muscle, respiratory physiology and general metabolism, orthopædic surgery, and of rehabilitation and psychology of chronic disability, especially in the young.

Orthopædic surgeons are largely responsible for the supervision of these cases in Britain, and though their organization is satisfactory in many respects, it is to be regretted that more attention has not been paid to the neurophysiological aspects of the problem. Further, the scientific testing of the methods used

has been largely neglected, so that we observe an astonishing assortment of methods of rehabilitation with little effort being made to assess their relative value.

Care of weak muscles

The first point to consider is the way in which the weakened muscles should be exercised There has already been reference to a misguided but widely prevalent belief that paretic muscles should be rested in a relaxed posture throughout most of the day, and that in severe cases the gradual return to freedom of movement should be spread over a period of 12 to 18 months Recently there has been a violent swing away from this view, and in certain clinics protagonists of progressive resistance exercises (Mead, 1950) advise vigorous active exercises from the earliest days of the disease, it is claimed that early exercises will achieve the maximum muscle recovery in a matter of weeks instead of months or years required by other methods

The treat-the-muscle-gently school of thought claims that their cases ultimately do best, and that they have observed that harm follows fatigue or when the muscle is allowed to escape from its splinted position of relaxation To this view it seems reasonable to argue that the effect of deliberately induced fatigue in these muscles has not been satisfactorily studied, and that the prolonged maintenance of a partially denervated muscle in a relaxed posture may make it artificially vulnerable to stretch, which may be the cause of apparent deterioration when splinting in a relaxed posture is discontinued As will be shown later, the author has failed to confirm that deliberately induced fatigue does harm to paretic muscles in the recovering stages of poliomyelitis

Certainly it seems reasonable after the first two or three weeks of the acute stage that there should be a complete change in the handling of the patient Any risk of aggravating the spinal cord damage has now presumably passed, and the rate of rehabilitation should be steadily increased so that after two further months the patient is spending a considerable part of his day exercising weak muscle groups Resting weak muscles ceases to serve any useful purpose after the early weeks of the major illness, as the spinal cord cells affected by the disease have probably either disappeared

or recovered a healthy appearance (Howe and Bodian, 1942) within one or two months from the onset of the major illness. In this changed situation *physiological fatigue of weak muscles* should provide the best natural stimulus to hypertrophy

Traditional methods of resting muscles in relaxed postures for many months are being rapidly revised, especially in America where "progressive resistance" exercises are being used during short periods of hospital treatment, the intermediate periods being spent at home (Mead, 1950). The deliberate avoidance of exercises for unaffected muscles antagonistic to paretic muscles has theoretical possibilities which are worth exploring for the prevention of deformities.

It seems likely, therefore, that the traditional rate of rehabilitation is undesirably slow, but research is required to ascertain the optimum method of exercising weak muscles under different conditions.

Methods of testing rehabilitation methods

Measuring muscle strength. The first need in the scientific study of muscle recovery is to provide a reasonably accurate method of testing muscle strength For this purpose certain muscles (such as biceps or triceps group) are much easier to test than others, and may be used in the first instance.

The 0 to 5 method of scoring on muscle charts, though a valuable part of the record and treatment, is unsuitable for a detailed study of the rate and degree of recovery of a particular muscle group. For this purpose some measuring device must be used so that the actual strength of a few muscle groups in each case may be charted once or twice a week. It is obvious that the conditions and positions under which each measurement is made must be as constant as possible. Simple spring balances are adequate for practical purposes, but the position of the limb must be the same at the moment when each reading of the spring is taken (Fig 24 (*a*) and (*b*)). An angle of 90° is convenient for muscles acting on the elbow, knee or hip.

A recording dynamometer will provide a useful record not only of the maximum strength but also of the rate of fatigue under different conditions (Figs 25, 26, 27)

For the muscles of respiration a measure of the vital capacity



(*a*)



(*b*)

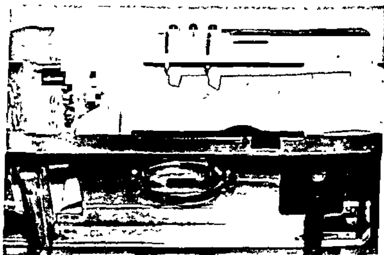
FIG 24 (*a*) —A simple spring device to measure the strength of a triceps muscle

Note that gravity is excluded and the record taken with the elbow at 90 degrees

(*b*) —Spring device used to measure strength of hamstrings



(a)



(b)

FIG. 25 (a) and (b).—A recording dynamometer designed by Dr. Edgar Schuster, O.B.E.

This is most easily used to measure grip (Fig. 27), but may be adapted to other muscle groups (Fig. 26). The dynamometer is manufactured by H. G. East & Co., 37A, Oxford Road, Cowley, Oxford.

is useful (Fig 28), while the strength of the abdominal muscles corresponds to some extent with the strength of forced expiration, and this may be measured by blowing into a U-tube containing water.

Whatever method is used, it is quite possible to prepare *muscle*

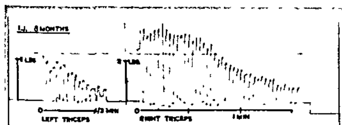


FIG. 26—Fatigue record on dynamometer of weak triceps muscles 3 months after onset of the disease

The patient (a young soldier) was instructed to make a maximum contraction and release at a rate of about 30 per minute

measurement charts for the approximate rate and degree of recovery from various initial levels of weakness This provides a base-line against which the value of all methods of treatment may be assessed

These simple methods were advocated by Lovett and Martin (1916) long ago, and are perfectly suitable for measurements of this kind, as the wide range of changes which occurs precludes greater accuracy.

Research report

As a contribution to the study of rehabilitation, Dr Fischer-Williams and the writer have recently been concerned with a study of muscle recovery (Russell and Fischer-Williams, 1954)

We attempted to record the rate of recovery of a few muscle groups in a number of cases over a period of a year or more The patients studied were retrained according to the following plan During the first 3 weeks of the acute stage complete physical rest was enforced, along with sedatives when they were considered safe. During the whole of this period, however, the patient's posture was changed every 2 hours, and the joints were

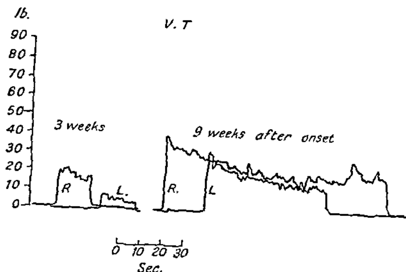


FIG 27.—Dynamometer recording of sustained grasp (right and left) from a girl, aged 11 years, at intervals of 3 weeks and 9 weeks after the onset of the disease.

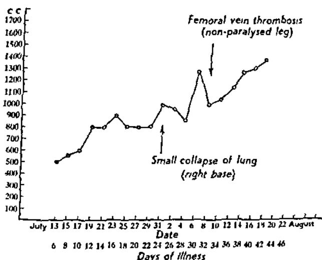


FIG 28 —Record of vital capacity during a period of 6 weeks after the acute illness

The patient, a married woman aged 32, was not treated in a respirator, but during the first 3 weeks her position in bed was changed every 2 hours The small atelectasis occurred after this strict routine was relaxed

passively moved by nurses every 4 hours Hot packs were only occasionally used for the relief of muscle pain After 3 weeks, active movements were encouraged to an increasing extent, special attention being paid to weak muscle groups Sling exercises were used freely; underwater treatment was not available.

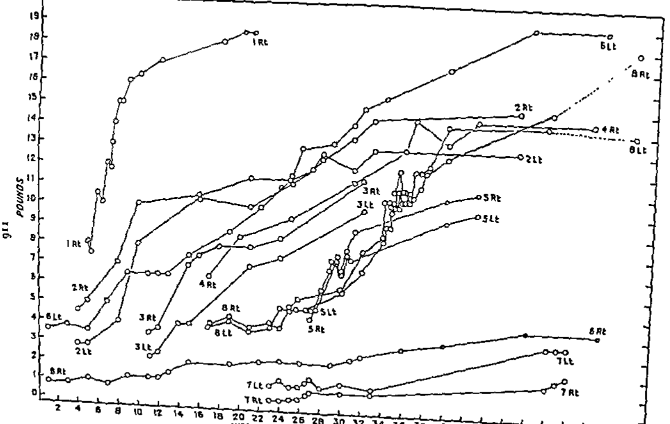
Within 6–8 weeks of the onset, standing and walking between parallel bars was begun for short periods with appropriate body support, even in the severe spinal and lower-limb cases In general the view was adopted that there need be little restriction of movements, provided that progress was satisfactory and that faulty habits and deforming postures were avoided In nearly 70 per cent of the fifty paralytic cases studied in 1952, the patients were allowed to return home within 3 months of the onset of the illness, provided that adequate outpatient physiotherapy and orthopædic supervision could be arranged.

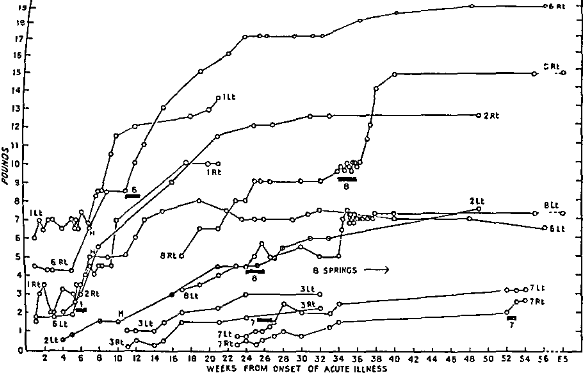
The measurements were made under uniform conditions as regards the position of the patient and examiner during the test All measurements were made by one of us (M. F -W)

With a little ingenuity most of the important muscle groups in the limbs can be tested For example, the thigh abductors may be measured while the limb is supported in slings

The cases studied were selected from seventy paralytic cases treated in 1952 and 1953. The muscle groups studied were those which were most suitable for measurement and were paretic but not completely paralysed in the acute stage It was also essential that the patient should be old enough to co-operate in the tests, the ages ranged from 9 to 40 years Otherwise the cases were unselected

Results. In this preliminary study the muscle groups used include flexion and extension at the elbow and the knee, the grip, and the vital capacity The results obtained from a large number of measurements may be presented in different ways. In Figs 29 and 30 the progress of recovery of the flexors and extensors of the forearm is shown for several different cases Fig 31 gives the progress of recovery for the thigh muscles in a few cases, and Fig 32 gives dynamometer readings These records indicate that improvement begins 3 or 4 weeks after the onset of poliomyelitis, and that there is a steady increase of strength for 30–40


POUNDS
1 Rt
2 Rt
2 Lt
3 Rt
3 Lt
4 Rt
5 Rt
5 Lt
6 Lt
7 Rt
7 Lt
8 Rt
8 Lt



POUNDS
WEEKS FROM ONSET OF ACUTE ILLNESS
6 Rt
5 Rt
1 Lt
2 Rt
1 Rt
6
8
2 Lt
8 Lt
6 Lt
8 Rt
6 Rt
H
B SPRINGS
1 Rt
2 Rt
1
3 Lt
7 Lt
7 Rt
3 Rt
7
2 Lt
3 Lt
3 Rt
7 Lt
7 Rt

FIG 31 —Recovery of thigh muscles

F, 31, 9, M, 10,
th week of polio-
eek her extensors

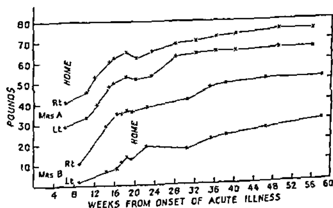


FIG. 32 —Progress of hand grip, shown by recording dynamometer in two women, Mrs A, aged 27, and Mrs B, aged 31.

weeks, by which time further recovery is becoming very slow, and in some cases has ceased.

In some patients (e g, Nos. 5 and 8 *) rapid improvement took place during the sixth month after the onset. Patient 5 had not, however, previously been encouraged to exercise vigorously Patient 8 had very weak deltoids, and quick improvement followed greatly increased arm movements, which were made possible by the fitting of springs and slings to provide floating support for both upper limbs in abduction while he sat in his chair In all these curves the rate of recovery seemed to be fairly regular In particular there were no rapid increases in strength, as might be expected if nerve regeneration played an important part in recovery

Experiments with Fatiguing Exercises

During the period of observation we introduced experimental periods of intensive exercise to one muscle group lasting 5 minutes once an hour for 10 hours a day, and this was continued for a week These periods of intensive exercise were not standardized in detail; some consisted in repeatedly raising a weight with the muscle group exercised, the weight being over half the maximum which could be raised on one occasion In other cases the exercises were carried out against springs appropriate to the strength of the muscles exercised

These frequently repeated and intensive exercises were generally continued for a week It should be repeated that these special exercise periods, marked in the figures, were added to an already active régime

As seen from the figures, these special exercises often had no very obvious effect on the curve of recovery, so far as maximum strength is concerned. The curve of recovery, however, continued during the period of special exercise, and in some instances a quickening of the rate of improvement followed the exercises Serious weakening of the exercised muscles was not observed in any case

During these repeated exercises, even though the maximum strength of the muscle changed little, it was often noticeable that

* The case numbers in this section refer only to the case numbers in Figs 29 and 30

the number of times the weight could be lifted increased considerably. This was well seen in patient 8 (Fig 33), and this observation emphasizes that maximum strength is not the only factor in muscle efficiency.

is here being used in the physiological sense in which repeated

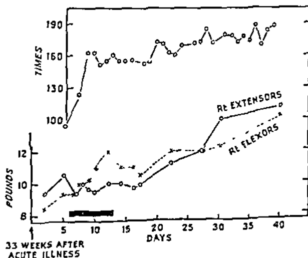


FIG 33 —Upper register records number of times right forearm could extend against 5 lb resistance Lower register gives maximum strength of right forearm flexors and extensors during the same period.

Solid bar, period of intensive exercises to extensors

movement leads to a temporary reduction in strength We have not yet studied in much detail the effect of long periods of weight-bearing, walking, etc, in association with very weak muscles. In this connection it may be pointed out that weakening of muscles after excessive weight-bearing may be caused not by fatigue but by stretching of a muscle which is not only weak but also tight This possibility did not, of course, arise in our experiments

The measurement of several muscle groups was continued after the patient returned to an active life at home; and, as can

be seen from the figures, this return was often followed by an acceleration of the rate of recovery of the muscle groups being measured The recovery of the muscles of respiration is of special interest because they can never rest for long and because their recovery can be measured by the vital capacity (Fig 28) Their rate of recovery is in many ways similar to that in limb muscles, and has been reported by Schuster and Fischer-Williams (1953)

In Fig 34 the rate of recovery of four muscle groups is given

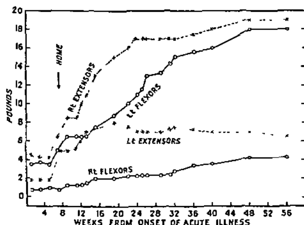


FIG 34 —Recovery of four upper-limb muscle groups in one patient (Mrs A), the weakest of which (Rt flexors) were submitted to special exercises in the 10th and 11th weeks of the illness

while one *of these was submitted to a special exercise period* This record illustrates that, while the weakest muscles are increasing in strength, so also may be the others, and it is therefore unlikely that imbalance can be corrected by this type of exercise In this connection other methods may prove more effective

Analysis of these figures gives some indication of the rate of increase in the strength of paretic muscles when these are treated on the lines described In several cases there was a fourfold increase in strength 6 months after onset of the illness compared with that at 1 month The increase, however, was less in some of the very weak muscles, and it will be particularly interesting

to compare the rate of recovery recorded in this series with that obtained with other types of treatment. It may be, for example, that the optimum vigour of exercising and retraining varies with different muscles and different degrees of paresis It will also be important to record whether the use of hot packs or underwater exercises is associated with a quicker rate of recovery than that observed with the simpler methods used here

In this series the limbs were treated without any rigid splinting in the acute stage of the illness apart from boards to support the feet; the joints were moved passively, and the posture was changed 2-hourly. There was thus little or no muscle tightness to interfere with measurements made 3 or 4 weeks after the acute illness began Other methods of handling the acute stage of poliomyelitis may influence the first readings for charting purposes, but this should not prevent comparison of the later stages of recovery under varying conditions.

Physiology of Recovery

The pattern of muscle recovery indicated in these charts is difficult to explain In the first place, as has been mentioned, there is no step at any stage in the curve which would suggest nerve regeneration as seen in recovering nerve injury Recovery may depend firstly on hypertrophy of the surviving muscular or neuronal elements (Edds, 1950), and secondly on a reorganization of the connections to the surviving motor cells. The organization of the neuronal pool is more alterable than was generally thought possible (Eccles, 1953); and, if some such reorganization takes place, the best results will be obtained by the patient's own determined efforts to move the weak limb. This may indeed explain the well-known but surprising achievements of the patient really determined to stimulate his weak muscles. As Robert Lovett wrote in 1916·

> *Muscle training* attempts to drive an impulse from brain to muscle to enable it if possible to open up new paths around affected centres in the cord

The type of measurement used in this investigation seems to be an essential part of the assessment of different types of treatment, and should in the writer's view have been widely adopted

long ago by those who treat poliomyelitis Physiotherapists can easily learn to make measurements of this kind, but there seems to be a widespread disinclination to measure progress accurately. It is clearly an essential step to take if sense is to be made out of the present state of confusion regarding the treatment of paretic muscles.

Muscle fatigue

The suggestion put forward by the writer in the first edition of this book, that muscle fatigue is the best treatment for paretic muscle, has been widely criticized, for the avoidance of fatigue is a traditional sheet-anchor of treatment in many clinics. However, it should be pointed out that fatigue as used here means exercise to the point of the muscle becoming much weaker, say one half of its original strength, and this may develop in less than 5 minutes, so that exercise to the point of fatigue in such a muscle would involve only 5 minutes of exercise

In passing it may be mentioned that severe fatigue of a normal muscle becomes apparent by severe pain developing in the muscle, but in the case of severely paralysed muscles no such pain develops, indeed, fatigue involves no sensation in the weak muscle, there is simply loss of strength Thus, when such muscles are exercised to the point of physiological fatigue, the patient has no feelings of fatigue or of over-exertion It is also obvious that any observed weakening of muscles treated would naturally require reduction of the amount of exercising, but in practice this rarely happens. In any case the patients here studied were subjected daily to muscle fatigue, and the rate of recovery has been recorded It remains to be shown whether other methods or rates of rehabilitation achieve a better result So far the writer has found no reason to alter his view that many current methods of muscle re-education in poliomyelitis are so timid as to be unphysiological and even harmful

CHAPTER XII

PHYSIOTHERAPY

THE physiotherapist is all-important during the stage of recovery, but she must prevent her methods from getting into rigid patterns, and should attempt to maintain a critical attitude to all she does

Muscle Charts

To the physiotherapist will probably fall the task of preparing a muscle chart so that all weak muscles can be identified. Unfortunately, the usual 0–5 method of muscle charting is not really suitable for cases of poliomyelitis. For example, grade 3 represents movement against the force of gravity. But a mere 2 per cent of the flexor digitorum muscle will move the fingers against gravity, whereas for the hip-flexors or abdominal muscles, well over 50 per cent of normal is required. What poliomyelitis cases require is an assessment of the fraction of muscle which is operating, and this can sometimes be done by a record of percentage of the normal.

Muscle charts are never very accurate, but they are none the less of great importance in assessing the best plan for treatment, and they should be supplemented by muscle measurement charts (see p. 111)

Muscle treatment

The physiotherapist must learn not only to identify the weak muscles which most require strengthening but also to recognize any restrictions in the range of movement of muscle or joint which may interfere with rehabilitation For example, a few *degrees of flexion contracture at the hip joint* will seriously interfere with early attempts to walk. The limitations of the *range of movement may be corrected:*

(1) By frequent passive movements to stretch the tight muscles, which *should be given every few hours* by a nurse or relative when a physiotherapist is not available.

(2) By exercises designed to increase the range of movement, and for this purpose the Guthrie-Smith slings with spring support are valuable (Fig. 35)

(3) The patient's day should be planned so that he can treat himself to some extent For example, abduction slings for the arms (supported with springs) greatly assists recovery of weak shoulder muscles



FIG 35—The use of slings and springs to improve the conditions for exercising abduction paresis

Some muscles are of course much more important than others and much thought should be given to devise methods which will be most profitable considering the time available

It is first necessary to identify those weak muscles which need most attention from the point of view of the patient's functional recovery Groups such as thigh abductors may need special attention, as will the shoulder-fixing muscles which are essential if crutches are to be required Where two opposing muscles are respectively strong and weak, exercises for the weak muscles only should be planned, while use of the strong group is discouraged This is important where the trunk muscles on one side only are weak. The patient should attempt to learn not only to exercise the weak side, but to refrain from allowing the strong side to exert its full strength or to cause deformity

Exercises to trunk and pelvic muscle groups require most planning, and slings to relieve the burden of gravity are valuable

in this connection, as also are carefully planned underwater exercises in a therapy pool.

Trick movements

Trick movements, such as offend the well-trained physiotherapist, need not always be discouraged, as their use may indicate that one muscle group is severely or even hopelessly paralysed.

There is a highly skilled group of physiotherapists who study individual muscle training in recovery from poliomyelitis, and to whom the exact pattern of movement requires most detailed training and study. Admirable though much of this special exercise work is, it is sometimes *unnecessarily restrictive* and discouraging to the patient who wants to move about as much as he can. Further, it may with confidence be suggested that *the spinal cord is probably the best judge as to the most efficient* way to deploy its limited resources after poliomyelitis, and that trick movements may often be encouraged with advantage, and *not discouraged. However, here again is an opportunity to* experiment and to compare the progress of cases in two units, one of which allows trick movements to be used freely.

The patient's psychology

Whatever methods are used, it is quite certain that the patient must be kept keen and always trying. If he becomes lazy and indifferent, then that will do much harm, for the patient's own determined effort is much the most powerful factor available to get the best possible degree of recovery in the muscles affected

After the first 6–8 weeks in hospital, and where prolonged hospital care is required, it is often possible to arrange for convalescent patients to go home for two nights each week-end under conditions which do their muscles no harm and do their morale much good

Heat, massage, electricity, etc

The chief purpose therefore of physiotherapy is to train the

patient to exercise the important weak muscles, to prevent any muscles becoming tight and to avoid deformity. In addition, however, the paralysed limb must be kept warm, and the best way to do this before treatment is to warm the body as a whole—not the cold limbs only—and a hot air bath to the trunk is a good method of doing this.

Diathermy to the spine has been advocated, but can have little effect apart from warming the patient It should on no account be used in the acute stage of the disease, as it may then be harmful.

Massage is little used now in poliomyelitis, but is of course soothing and beneficial to the circulation

Hopeless muscles

Electricity is of more value in diagnosis than treatment The strength duration curve (electrical reactions) will help to identify the hopeless muscles, but the best method (Brooks, 1953) is to stimulate electrically the nerve to the paretic muscle when the muscle fibres which can recover voluntary movement will contract, whereas the nerve fibres to muscle which does not move are degenerated, and no regeneration (as far as is known) occurs in poliomyelitis

It is possible that electrical stimulation of weak muscle groups may assist re-education at a certain stage, but it should always be remembered that the determined effort by the patient is always a better stimulus to recovery of function than anything else

Prevention of deformity

The avoidance of deformity comes last in this book, not because it is least important, but because in the more recent history of the subject it has too often come first, to the exclusion of other vital parts of rehabilitation and treatment The history of the various measures used to prevent deformity during the past forty years makes depressing reading, for much harm has

been done in attempts to avoid deformity, and many methods still in use do not bear critical scrutiny.

Some deformities are very difficult to prevent, for even where the prevention of deformity is considered to be the first requirement of rehabilitation, the results of treatment directed to the avoidance of deformity are at times extremely disappointing

Deformity due to muscle imbalance

If a paralysed muscle is opposed by normal muscles, deformity is liable to occur. Such deformities vary greatly in their importance: thus, a limited degree of flexion contracture at the elbow may be advantageous. On the other hand, adduction contracture of the arm in cases of deltoid paralysis should not be allowed to develop. Similarly, the flat ("ape") hand resulting from paralysis of the thenar muscles should be avoided.

In the lower limb a variety of foot deformities may result from muscle imbalance, but many of these are counteracted by weight-bearing with, if necessary, a light below-the-knee caliper giving spring support to the foot as required These cases can often be treated "on their feet" with suitable appliances, but if there is a flail ankle or knee joint a caliper may be required to render weight-bearing safe.

In the thigh an adductor deformity may occur when the danger of this is not adequately countered in the early weeks after the acute illness, and of course the all too common flexion contracture at the hip which is due to a failure to insist on the use of the prone posture for 2 or 3 periods daily as a part of the treatment routine.

In the upper limb deformities due to muscle imbalance present a different problem, as functional usefulness here is more important than stability. Operations to improve function include arthrodesis at the shoulder or elbow and transplantation of tendons in the forearm and hand (Seddon, 1954).

Rigid forms of splinting to the hand and fingers should rarely be used, and then only for limited periods each day. The full range of movement of fingers and wrist should be maintained by frequent passive movements performed several times a day. This involves stretching the weak muscles as well as the strong

through their full range of movement If this point is neglected the weak muscle will become short and thus dangerously vulnerable to stretch.

The chief measures required to prevent deformity by muscle imbalance are therefore:

1. Frequent passive stretching of the dominant muscle groups This should not be left entirely to the physiotherapy sessions, but should be done by the nurse, the relatives, or the patient himself, whichever is appropriate.
2. Posturing of the limbs with pillows or at times with light splinting, partly in order to give the paralysed muscles a period at least of full relaxation, and partly to prevent the limb from remaining too long with the strong group in a shortened position
3. Exercises designed to increase the strength of the weaker muscle group These may be assisted greatly by some form of lively support which aids the weak muscle groups

Sling suspension of the limbs with the Guthrie-Smith apparatus is most helpful in these cases, but the movements exercised should be restricted by springs in order to limit the range of swinging the limb, as swinging a suspended limb often becomes something of a trick movement

Failure of static body support

In order to stand without support, the muscles of the trunk and pelvic girdle are specially important If the arms and shoulder-fixing muscles are strong, the problem is relatively simple, for however weak the lower limbs, strong arms and shoulders will be able to support the body weight with crutches, as can be achieved in cases of spinal cord transection

Even when the shoulder girdle muscles are unable to support much weight, the exercise of standing between bars and attempting to walk is highly beneficial Exercises under water are specially valuable in the very severe cases for whom out-of-water

attempts to stand are unsuccessful Fig. 36 illustrates such a patient attempting to walk between parallel bars.

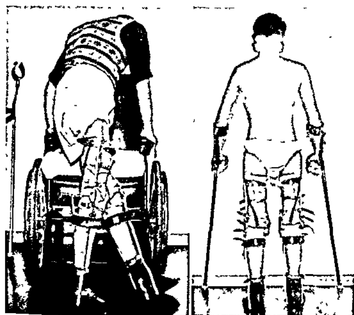


FIG 36 —Severe paralysis of trunk and lower limbs with weakness of shoulder girdle muscles Walking exercises, with temporary splints to support knees.

Paralysis from the waist downwards

The young man in Figs 37 (*a*) and (*b*) was completely paralysed from the waist downwards, while the muscles above this level were normal It became early apparent that no useful function would return in the lower limbs, so that there was no object in prolonging hospital treatment unduly. He was therefore trained to walk with calipers and returned home and to work within five months of the onset of the illness These illustrations show the patient getting out of his wheel chair.

It is also possible to teach these patients to take a few steps without calipers by locking the knee backwards, and in some



(a) (b)

FIG 37—Complete paralysis from the waist down Arms and upper trunk normal

Training for a wheel-chair life, but also for being able to get out of the chair himself and walk slowly with elbow crutches

instances this proves to be better in practice than the more clumsy, but secure, standing with calipers In Fig 38, for example, is a young married woman who was able to do most of her cooking and housework from a wheel chair, and was able to stand up and take a few steps by locking her knee backwards For a week she tried to use calipers, but it became clear that she could do more at home without leg splints of any kind.

Paralysis of one leg

Severe paralysis of one lower limb only provides a special problem, especially in young children Early weight-bearing under supervision is beneficial, but the young patient soon tends

to become too active and the flail knee joint may become unstable, whilst the weak pelvic girdle on one side leads to pelvic tilt and compensatory scoliosis A full length caliper may be used as a method of protection, and the amount of walking allowed should be restricted.



FIG 38 —Severe trunk and lower limb paralysis

Does her housework and cooking from a wheel chair wearing a spinal brace, but also trained to get out of her chair and walk slowly without calipers by means of locking the knees backwards

In children, every effort should be made to keep the weak leg as warm as, or warmer than the strong, lest a difference in temperature should contribute to a slowing in growth in the paralysed leg

Combined shoulder-girdle and trunk weakness

The really troublesome cases are those which have severe paralysis of trunk, spinal and pelvic girdle muscles, and in

addition weakness of the shoulder-girdle muscles which precludes weight-bearing by the arms This presents a special problem, for there is no possibility of the patient supporting himself on his legs or even on a chair without some form of appliance to keep him straight.

Standing, and attempts to walk form a valuable exercise for all; and sometimes, with axillary crutches and perhaps a splint to maintain elbow extension, a few steps become possible Under-water walking exercises are specially helpful for this type of case



Fig 39—Severely paralysed children playing on a floor of mattresses

In young children, however, there are special difficulties as deformities are hard to prevent over the growing years The spine is apt to concertina into a severe kypho-scoliosis with various degrees of pelvic tilt. Even a wheel-chair life is dangerous for these patients, as it is difficult to provide a brace for sitting which really prevents deformities from developing It is clear therefore that this group, and this group of cases only, requires prolonged periods of care in the lying position, much of which should be spent in the prone posture It is of course desirable that periods of sitting up be allowed every day, but during the growing years a considerable part of each day should be spent lying These children must of course be encouraged to move about as much as they can, and a useful method is to cover an

area of floor with several mattresses and allow them to roll about as they wish. Most learn to roll over and over, and greatly benefit from this freedom of movement (Fig. 39) Even under these conditions, however, there are special problems, one of which is a tendency for the shoulders to be raised by muscle shortening of the upper trapezius muscle. Periods of well-supported sitting counteract this to some extent, as gravity will then pull the shoulders down again. The device shown in Fig 40 is a popular toy with these children.



Fig. 40.—This wheeled stretcher can be operated by this child with severe trunk, lower limb and shoulder-girdle paralysis

Many of these gravely crippled children tend to develop some degree of spinal deformity which is very difficult to correct. Immobilization in plaster beds or on spinal frames is of limited value, and treatment by frequent stretching of the tight muscles may achieve more, and is better tolerated

Some general principles of rehabilitation

In general, the patient recovering from poliomyelitis should be encouraged to work hard at strengthening his weak muscles with all the freedom he can possibly be given, provided that postures and activities which will lead to deformity can be avoided.

Where the home conditions are good, most patients can be made safe to return home within 4 to 6 months of the onset of the disease, and many can safely go home much sooner.

However, when there are neither spinal nor shoulder-girdle muscles to support the body weight, great care and skilled supervision are required for an indefinite period. Very prolonged hospitalization is bad for everyone, especially children, and this should only be advised for specific reasons from which the patient will benefit.

The interests of education and treatment may clash seriously, and as good education is always doubly important to the cripple, great care must be taken to avoid anything which will handicap adult life unnecessarily. This specially applies to prolonged treatment of hopeless muscles or slight spinal deformity which often needlessly interferes with much more important matters concerned with the patient's future

Self-help devices

There is no end to the gadgets which can be invented to assist the disabled, and this aspect of resettlement is still much neglected Occupational therapy departments should be prepared to advise the patients in this matter, and arrangements should be made to carry out structural alterations in the patient's home so that as useful and independent a life as possible can be led An illustrated list of such devices can be obtained on application to The Institute of Physical Medicine, 400 East 34th Street, New York 16, N.Y, U S A Dr Cooksey's demonstration of the kitchen (1952) for the disabled housewife is also most helpful

CHAPTER XIII

FUTURE PROSPECTS

Most civilized countries are at the moment preparing a programme for the immunization of children against poliomyelitis, and by the time these words are read many such plans will have been made public.

Most virologists expected that the method chosen would depend on the use of attenuated strains of the virus administered perhaps by the mouth as advocated by Koprowski (1954) and Sabin (1955), and indeed it seems that this method is now available to protect the individual. Unfortunately, however, although this seems to be the most effective method, the theoretical risks of the virus acquiring virulence in the intestines of those protected, is preventing, or at least delaying, a full trial of this method. This leads to a disappointing and somewhat confusing state of affairs, for use of the inactivated viruses as advocated by Salk have proved to be more effective than most virologists expected, with the result that this last method is to be the one that will be widely used in the next year or two. Fatal accidents were reported in the spring of 1955 from the use of "inactivated" virus, but these dangers seem to have been largely removed, and some millions of European and American children will be inoculated with inactivated viruses during 1956. For the European programmes the Mahoney strain of type 1 virus (which caused the accidents in U.S.A.) will not be used With this and other modifications the vaccines to be used in Europe are now thought to be safe, and the further trials have been approved by the *Association Européene Contre la Poliomyelite* at their meeting in Zurich in October 1955

We seem therefore to be on the way to conquering poliomyelitis in its paralytic form, and all possible support should be given to those scientists who bear the heavy responsibility of advising their Governments. Hurrying scientists in a matter of this sort is dangerous, and yet when a safe method of protection

becomes known we are bound to make the vaccine available to all at the earliest possible opportunity.

Even if paralytic poliomyelitis should disappear from medical experience, the intensive study of this disease will not have been wasted, for the many lessons learned can be applied to the study of other diseases of the nervous system

REFERENCES

AINSLIE, J. D. (1952). "The effect of sodium monofluoroacetate and methionine sulfoximine on the early phase of growth of the virus (Lansing strain)", *J. exp. Med.*, 95, 1 and 9.

ALBRECHT, R. M. and LOCKE, F. B (1951). "Effect of physical activity on prognosis of poliomyelitis", *J. Amer. med Assoc.*, 146, 769

BANG, C. (1953). "A new respirator", *Lancet*, 1, 723.

BEAVER, R. A. and BYFORD, G H. (1954). "A machine for assisted and positive pressure breathing", *Lancet*, 1, 1014.

BEAVER, R. A. and GILLIATT, R. W. (1953). "Mouthpiece for use with pneumoflator in respiratory paralysis", *Lancet*, 2, 1243.

BECK, C. J. and BARACH, A. L. (1954). "Value of mechanical aids in the management of a patient with poliomyelitis", *Ann Int. Med*, 40, 1081

BIBLIOGRAPHY OF INFANTILE PARALYSIS, 2nd edition, 1789–1949 Lippincott. Philadelphia.

BODIAN, D (1948). *Trans* 1st Internat. Poliomyelitis Conference. Lippincott Philadelphia.

—— (1952) "A reconsideration of the pathogenesis of poliomyelitis" *Amer J. Hyg.*, 55, 414.

—— (1954) "
effects of in

BODIAN, D. and ...
in the chimpanzee", *J. exp. Med.*, 81, 255

BODIAN, D. and PAFFENBARGER, R. S. (1954) "Poliomyelitis infection in households frequency of viræmia and specific antibody response", *Amer. J. Hyg*, 60, 83.

BOURDILLON, R B, DAVIES-JONES, E., STOTT, F D and TAYLOR, L M (1950) "Respiratory studies in paralytic poliomyelitis", *Brit med J*, 2, 539

BOWER, A G, BENNETT, V R, DILLON, J. B and AXELROD, B. (1950) "Investigation on the care and treatment of poliomyelitis patients", *Ann West. med. Surg*, 4, 561.

BRADLEY, W H (1950) "Some notes on poliomyelitis", Monthly Bull, Ministry of Health, 9, 203

BREHME, TH and LEUTERER, W. (1953) "Schlaftherapie bei poliomyelitis; versuch einer Lähmung prophylaxie mit sedativmitteln", *Münch. med Wschr*, 95, 751.

BROOKS, D. (1953) "Nerve conduction in poliomyelitis", In *The Spinal Cord Symposium* Churchill · London

CANCER CELLS (1954)—Editorial, *The Medical Officer*, 91, 185

COOK, D D and GERARD, R W (1931) *Amer. J Physiol*, 97, 412.

COOKSEY, F S (1952) "Rehabilitation of the disabled housewife", *Ann Phys Med*, **1**, 120

COURNAND, A, MOTLEY, H L, WERKO, L and RICHARDS, D W (1948). "Physiological studies of effects of intermittent positive pressure breathing on cardiac output in man", *Amer J Physiol*, **152**, 162

CRAMPTON-SMITH, A, SPALDING, J. M K and RUSSELL, W R (1954) "Poliomyelitis: artificial respiration by intermittent positive pressure", *Lancet*, **1**, 939

DAIL, C W (1954). "Glosso-pharyngeal breathing". See SPENCER, W A. (1954). *Treatment of Acute Poliomyelitis* Thomas Springfield, Ill.

DELBRUCK, M. (1951) *Trans* 2nd Internat Poliomyelitis Conference

ECCLES, J. C. (1953) *The Neurophysiological Basis of Mind* Waynflete Lectures, 1952, Chapter 6 O U P. Oxford

EDDS, M V (1950) "Hypertrophy of nerve fibres to functionally overloaded muscle", *J comp Anat*, **93**, 259

ENDERS, J. F (1951) *Trans* 2nd Internat Poliomyelitis Conference

ENGSTROM, C.-G (1954) "Treatment of severe cases of respiratory paralysis by the Engstrom universal respirator", *Brit med J*, **2**, 666

'E, F. C (1932) "Actuation of the inert diaphragm by a gravity method", *Lancet*, **2**, 995

FRANCIS, T (1952) "Distribution of poliomyelitis virus in the epidemic community", *Trans Assoc Amer Physicians*, **65**, 176

GEFFEN, D, PATERSON, J H and TRACY, S M (1953) "Poliomyelitis following inoculation a survey of 29 children", *Lancet*, **1**, 1268

GOWERS, W. R (1892) *Diseases of the Nervous System* 2nd edition Churchill London

HARRIES, J R and LAWES, W E (1955) "Intermittent positive pressure respiration in bulbo-spinal poliomyelitis", *Brit med J*, **1**, 448

[H]ARRINGTON, A B (1951) "Paralytic poliomyelitis following injury", *Lancet*, **1**, 987

[H]IGGINS, G, LEWIN, W S, O'BRIEN, J R P and TAYLOR, W H (1954) "Metabolic disorders in head injury report of 76 consecutive cases", *Lancet*, **1**, 61

HILL, A B and KNOWELDEN, J (1950) "Inoculation and poliomyelitis", *Brit med J*, **2**, 1

HODES, R, PEACOCK, S M and BODIAN, D (1949) "Selective destruction of large motoneurons by poliomyelitis virus", *J Neuropath exp Neurol*, **8**, 400

HOFFMAN, H (1950) "Local re-innervation in partially denervated muscle", *Aust J exp Biol med Sci*, **28**, 383

HORSFALL, F L (1951) *Trans*. 2nd Internat Poliomyelitis Conference.

HORSTMANN, D (1947) "The incubation period in human poliomyelitis and its implications", *J. Amer. med. Assoc.*, 135, 11
—— (1949). "Clinical aspects of acute poliomyelitis", *Amer. J. Med*, 6, 592.
—— (1950). "Acute poliomyelitis. Relation of physical activity at the time of onset to the course of the disease", *J. Amer. med. Assoc.*, 142, 236.
—— (1952). "Poliomyelitis virus in blood of orally infected monkeys and chimpanzees", *Proc. Soc. exp Biol and Med.*, 79, 417.
HORSTMANN, D and MCCOLLUM, R. W. (1953). "Poliomyelitis virus in human blood during the 'minor illness' and an asymptomatic infection." *Proc. Soc exp. Biol.*, 82, 434
HORSTMANN, D. and PAUL, J. R. (1947). "The incubation period in human poliomyelitis and its implications", *J. Amer med. Assoc.*, 135, 11.
HOWE, H A and BODIAN, D. (1942) *Neural mechanisms in poliomyelitis.* The Commonwealth Fund: New York.
HYDEN, H. (1943) "Protein metabolism in the nerve cell during growth and function", *Acta physiol. scand (Suppl. 17)*, 6, 1.
KELLEHER, W H., KINNIER WILSON, A B, RUSSELL, W. R. and STOTT, F D (1952). "Cuirass respirators", *Brit. med. J*, 2, 412
KOPROWSKI, H, JERVIS, G. A, NORTON, T. W. and NELSEN, D J (1953). "Further studies on oral administration of living poliomyelitis virus to human subjects." *Proc. Soc. exp. Biol*, 82, 277.
LASSEN, H C A. (1953). "The 1952 epidemic of poliomyelitis in Copenhagen, with special reference to the treatment of acute respiratory insufficiency", *Lancet*, 1, 37.
LENARSKY, M, PARR, R L and SEANOR, H. E. (1951). *Amer. J. Dis. Child*, 82, 160
LEVINSON, S. O, MILZER, A and LEWIN, P. (1945). "Effect of fatigue, chilling and mechanical trauma on resistance to experimental poliomyelitis", *Amer J Hyg*, 42, 204
LOVETT, R. W and MARTIN, E. G. (1916) "Certain aspects of infantile paralysis, with a description of a method of muscle testing", *J Amer med. Assoc*, 67, 729
LUCCHESI, P F and LABOCCETTA, A C (1944) "Relationship of tonsils and adenoids to the type of poliomyelitis", *Amer. J. Dis. Child*, 68, 1
MACAULAY, J C (1954) "*Phrenic stimulation in the treatment of* acute bulbar poliomyelitis", *J Amer. med Assoc*, 155, 541.
MCCLOSKEY, B P (1950). "The relation of prophylactic inoculations to the onset of poliomyelitis", *Lancet*, 1, 659
MACINTOSH, R R (1953) "Oxford inflating bellows", *Brit. med. J*, 2, 202
MACINTOSH, R R and PRATT, C L. G. (1939). "The Oxford inflator: a simple resuscitator", *Lancet*, 1, 206

MACRAE, J., MCKENDRICK, G. D. W., CLAREMONT, J. M., SEFTON, E. M. and WALLEY, R. V. (1953) "The Clevedon positive pressure respirator", *Lancet*, 2, 971.

MARSHALL, J and SPALDING, J. M. K (1953) "Humidification in positive pressure respiration for bulbo-spinal paralysis", *Lancet*, 2, 1022

MEAD, S (1950). "Intermittent treatment of poliomyelitis with progressive resistance exercises", *J Amer med Assoc*, 144, 458

MEDICAL RESEARCH COUNCIL WAR MEMORANDUM No. 7. (1942). "Aids to the Investigation of Peripheral Nerve Injuries" H.M.S.O London.

MELNICK, J L. and GODMAN, G. C (1951) "Pathogenesis of coxsackie virus infection", *J. exp Med*, 93, 247.

MELNICK, J L and LEDINKO, N (1953) "Development of neutralising antibodies against three types of poliomyelitis virus during an epidemic period", *Amer J Hyg*, 58, 207

MELNICK, J L, RAMOS-ALVAREZ, M, BLACK, F. J, GIRARDI, A J. and NAGAKI, D (1954) "Poliomyelitis viruses in tissue cultures. VII Experiences with viral and serological diagnostic procedures", *Yale J Biol Med*, 26, 465

MINISTRY OF HEALTH (1953) National Health Service Circular, R H B (53) 75

MOTLEY, H L, COURNAND, A, WERKO, L, DRESDALE, D T, HIMMELSTEIN, A and RICHARDS, D W (1948) "Intermittent positive pressure breathing a means of administering artificial respiration in man", *J Amer med Assoc*, 137, 370

NURSING FOR THE POLIOMYELITIS PATIENT, 1948 Published by the National Organization for Public Health Nursing and the National League for Nursing Education, 790 Broadway, New York

PASK, E A. (1953) "A simple respirator", *Lancet*, 2, 141

—— (1955) *Proc Roy Soc Med*, 48, 239

PAUL, J R., MELNICK, J L, BARNETT, V H and GOLDBLOM, N (1952) "A survey of neutralizing antibodies to poliomyelitis in Cairo, Egypt", *Amer J Hyg*, 55, 402

PEABODY, F. W, DRAPER, G and DOCHEZ, A R (1912) *Monograph No 4* · Rockefeller Institute for Medical Research

ROYAL COLLEGE OF PHYSICIANS (1953) 2nd Report of Committee on Poliomyelitis *Lancet*, 2, 707

RUSSELL, W R (1947) "Poliomyelitis the pre-paralytic stage and the effect of physical activity on the severity of paralysis", *Brit med J*, 2, 1023

—— (1949) "Paralytic poliomyelitis the early symptoms and the effect of physical activity on the course of the disease", *Brit med J*, 1, 465

—— (1952) "Poliomyelitis", *Edin med J*, 59, 530

RUSSELL, W R and SCHUSTER, E (1953) "Respiration pump for poliomyelitis", *Lancet*, 2, 707

RUSSELL, W. R. and FISCHER-WILLIAMS, M. (1954). "Recovery of muscular strength after poliomyelitis", *Lancet*, 1, 330.

SABIN, A. B. (1949). "Problems in the natural history of poliomyelitis", *Ann. intern. Med*, 30, 40.

—— (1955). "Behaviour of Chimpanzee—avirulent poliomyelitis viruses in experimentally infected human volunteers", *Brit med. J*, 2, 160.

SALK, J. E. (1953). "Recent studies on immunisation against poliomyelitis", *Paediat*, 12, 471.

—— (1954). "Studies in human subjects on active immunisation against poliomyelitis", *Amer. J. Publ. Hlth*, 44, 994.

SANDERS, M., SORET, M. G. and AKIN, B. A. (1953). "Neurotoxoid interference with two human strains of poliomyelitis in rhesus monkeys", *Ann. N.Y. Acad. Sc.*, 58, 1.

SARNOFF, S. J. *et al* (1948). "Electrophrenic respiration", *Amer. J Physiol* 155, 1.

SCHUSTER, E. and FISCHER-WILLIAMS, M. (1953). "Rocking bed for poliomyelitis", *Lancet*, 2, 1074.

SEDDON, H. J. (1952) "Review of the autobiography of Sister Kenny", *Brit. med. J.*, 1, 802.

—— (1954). "Treatment of Poliomyelitis", Part 2 in *Surgical Progress, 1954* Butterworth · London.

SMITH-CLARKE, G. T. and GALPINE J. F. (1955) "A positive-negative pressure respirator", *Lancet*, 1, 1299.

SPALDING, J (1955) "Pressure and duration of inspiration during I P P R", *Lancet*, 1, 1099

SPALDING, J. and YOUNG, S A (1955) "Testing apparatus for I.P.P R", *Lancet*, 2, 227.

SPENCER, W A (1954) *Treatment of Acute Poliomyelitis*, 2nd edition. Thomas Springfield, Ill.

STIMPSON, P. M. (1952). "Home care of patients with acute poliomyelitis", *J Amer. med. Assoc.*, 149, 719.

STOTT, C. and FISCHER-WILLIAMS, M. (1955). *Poliomyelitis . The Nurse's Handbook* Livingstone . Edinburgh.

STOTT, F D. (1953) "The laryngeal microphone as an aid to treatment in bulbar poliomyelitis", *Brit. med. J.*, 2, 1414.

SWARTZMANN, G (1950) "Enhancing effect of cortisone on poliomyelitis infection in hamsters and mice", *Proc. Soc. exper. Biol. N Y*, 75, 835

TAYLOR, L M, SMITH, H V and HUNTER, G. (1954) "The blood-C S F barrier to bromide in the diagnosis of tuberculous meningitis", *Lancet*, 1, 700

THIEFFRY, S (1947). *Le diagnostic de la paralysie infantile* Doin et Cie Paris.

TRUETA, J and HODES, R (1954) "Provoking and localising factors in poliomyelitis · an experimental study", *Lancet*, 1, 999

WERKÖ, L (1947) "The Influence of Positive Pressure Breathing on the Circulation in Man", *Acta med scand. (Suppl 193)*

WORLD HEALTH ORGANIZATION (1954) *Expert Committee on Poliomyelitis, First Report* No. 81. Geneva.

WRIGHT, Jessie (1947) "The Respir-aid rocking bed in poliomyelitis", *Amer. J. Nursing*, 47, 454

INDEX

Abdominal distension, 93
Antibiotics, 85
Antibody,
  level of, 6
" Armed truce ", 7

Bacteriophages, 46
Barriers to virus, 6
Biochemical control, 85
Blood pressure, 71, 85
Bronchoscopy, 84
Bulbar poliomyelitis, 29, 68

Cell vulnerability,
  effect of inoculations, 52
  — local trauma, 51
  — physical activity, 47 *et seq*
  — tonsillectomy, 52
  — transportation, 51
Cerebrospinal fluid, 42
Clinical course,
  atypical cases, 16, 28
  relapsing cases, 26
  variations in, 26
Clinical signs,
  air passages and lungs, 39
  extremities, 41
  mental state, 38
  physical examination, 37
  reflexes and sensation, 42
  trunk and respiration, 39
CO_2 meter, 71
Convalescence and rehabilitation, 108
Copenhagen method, 72
Coxsackie virus, 3
Critical hours of the disease, 8, 56

Deformity,
  due to failure of static body support, 129
  — muscle imbalance, 128
Differential diagnosis, 43

Electrolyte equilibrium, 83
Epidemiology, 11

Future prospects, 138

Glosso-pharyngeal breathing, 100

Historical, 1
Hospital,
  adequate requirements, 58
  admission of patient, 56
  mobile units, 57
  organization for epidemic, 61
Hot packs, 102, 104
Humidifier, 81

Immunity,
  absence of, 15
  acquired, 13, 18
Immunization,
  active, 14, 136
  passive, 14
Incubation period, 8
Infection,
  control of, 11
  route of, 1, 3
Inoculations and poliomyelitis, 52
Intermittent positive pressure respiration (I P P R), 72, 79
  disadvantages of, 87
  management of, 79
  wave form, 77
  weaning from, 87
Intubation, 81
Isolation,
  of contacts, 13, 14
  — patients, 13, 14, 57

Lumbar puncture, 63
Lung complications, 83 *et seq*

Mechanical coughing, 87
Ministry of Health circular, 59
Motoneurones,
  branching of, 10
  destruction of, 3
  enlargement of, 9
  number destroyed, 3, 9
  regeneration, 9

Muscles,
care of, 101
charts, 124
contracture, 102
fatigue, 110, 123
"hopeless", 127
hypertrophy of, 9
measuring strength of, 110
passive movements, 105
recording dynamometer, 110
recovery of strength, 9, 108, 122
relaxation, 103
shortening, 102
spasm, 101
splinting, 103
tenderness of, 42
trick movements, 126

Nurses,
training of, 59
Nursing,
for I P P.R, 86
— tank respirators, 92
passive movements, 64
poliomyelitis bed, 64
posture, 64
principles, 63
reports, 66

Oesophageal catheter, 73
Oxygen,
use with I P.P R, 77

Paralysis,
spread of, 20, 67
Physiotherapy,
to chest, 73
— muscles, 124 *et seq*
Postural drainage, 69
Prevention of disease, 11, 54
Prodromata, 16, 18
Prognosis of muscle power, 113, 127
Provoking factors, 54
Psychology, 63, 67, 126

Quarantine, 12

Radiology of lungs, 71
Rehabilitation,
rate of, 10, 134

Respiration, artificial,
adequate ventilation, 83, 92
blood pressure, 83
by I P P.R, 72, 79
— phrenic nerve stimulation, 98
new tank respirators, 88
weaning from respirators, 96
Respiration units, 60
Respirator units, 100
Rocking-bed, 99
Royal College of Physicians Committee, 58

Self-help devices, 135
Spinal cord cells, 9, 10
Stages of the disease,
major illness, 16, 19
meningitic, 6
minor illness, 16
paralytic, 16
pre-paralytic, 16, 35
Symptoms,
catarrhal, 16, 25
coma, 34
dysphagia, 29
head pain, 21
in infants, 35
neck pain, 22
pain in chest, abdomen and thighs, 23
paraesthesiae, 25
retention of urine, 35
spinal and root pains, 21
vertigo, 25, 29
vomiting, 16, 25, 29
Syringe infection, 55

Tendon transplanting, 128
Throat microphone, 70
Tonsillectomy and poliomyelitis, 52
Tracheotomy, 72
Transporting the patient, 79
Trauma and poliomyelitis, 51
Treatment,
abdominal distension, 93
analgesics, 63
barbiturates, 63, 67
bulbar poliomyelitis, 68
care of bowel, 94
"combined" cases, 71
development of paralysis, 62

Treatment—*continued*
during recovery phase, 108
hospital needs, 61
major illness, 56, 62
minor illness, 56
muscles and joints, 101
of weak muscles, 109
respiratory paralysis, 91
retention of urine, 94
Sister Kenny's methods, 103
splints, 103
Types of poliomyelitis,
abortive, 2, 6, 18
asymptomatic, 12
bulbar, 29 *et seq*
cerebral, 29
Types of poliomyelitis—*continued*
non-paralytic, 2
paralytic, 3

Vaccine, 14, 136
Virus, 1, 2
affinity for motoneurones, 3
distribution of, 12
in blood, 3, 16
— stools, 13
involvement of muscle, 3
pathway to central nervous system, 3
resistance to chemical agents, 2
— heat, 2
tissue culture of, 46